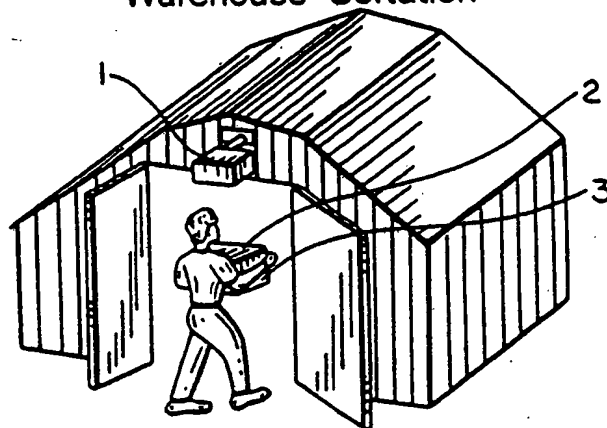


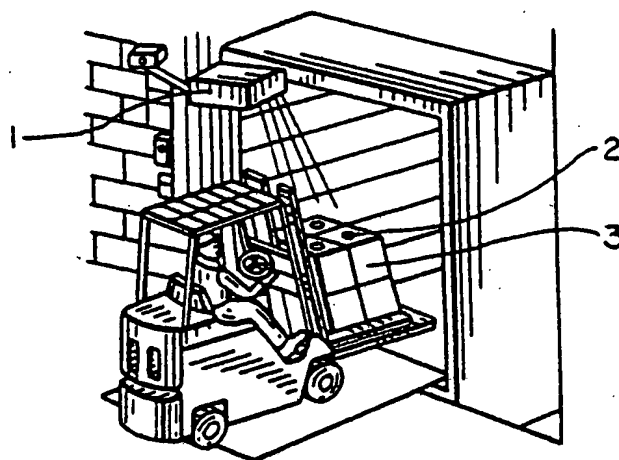
Warehouse Sortation

FIG. 1A



Container Loading

FIG. 1B



Bulk Package Loading

FIG. 1C



Rotation axis

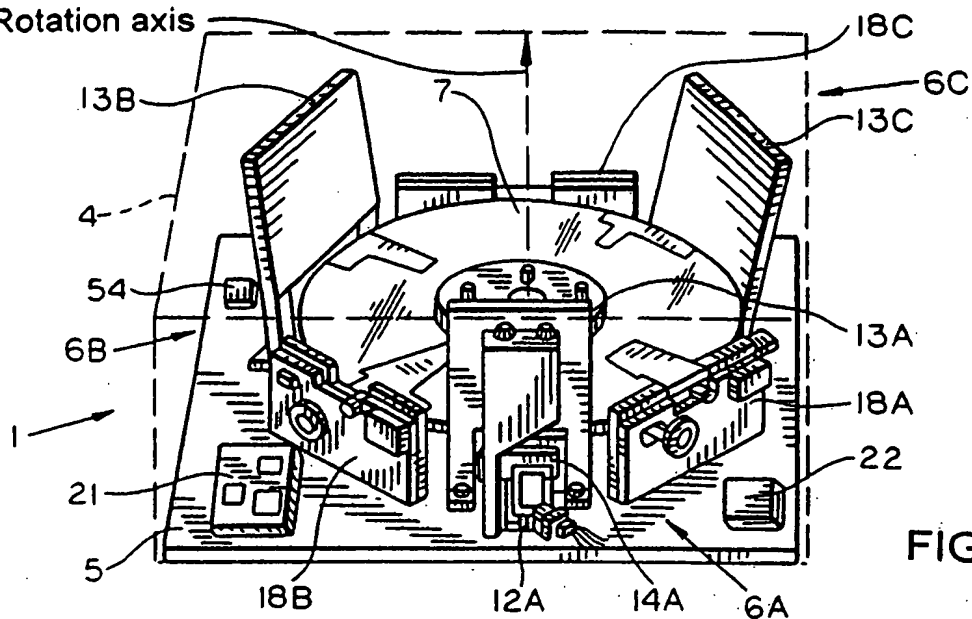


FIG. 2A

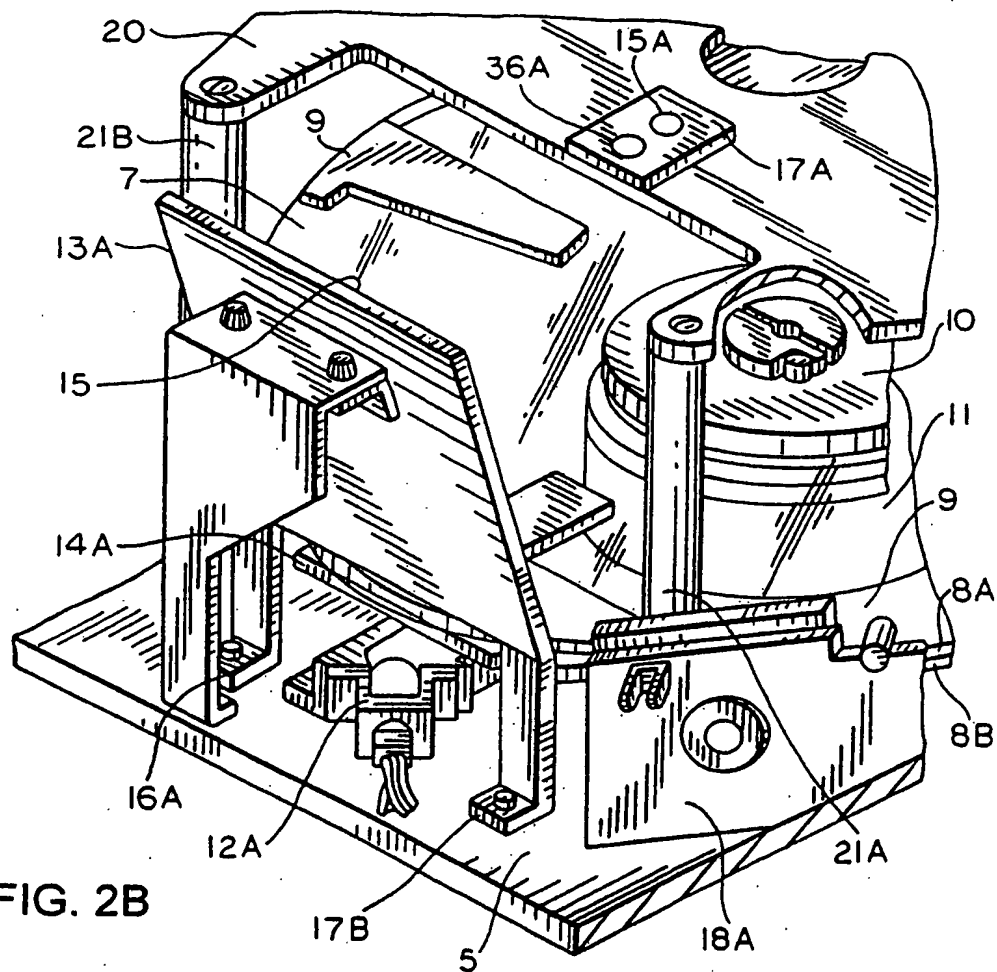


FIG. 2B

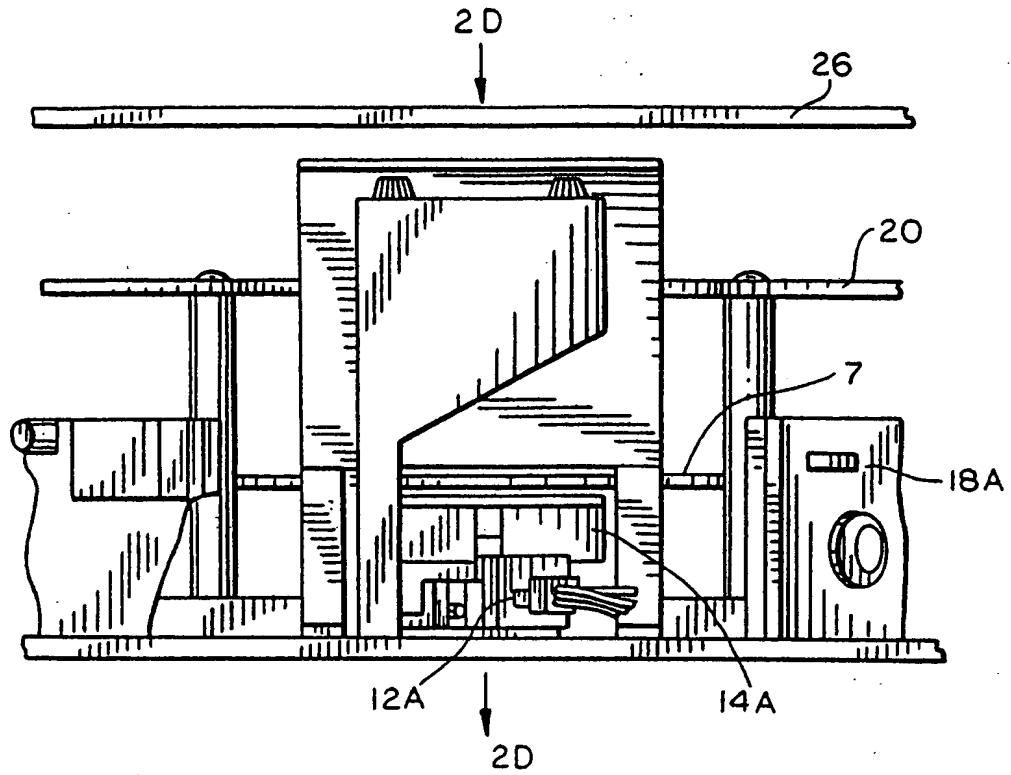


FIG. 2C

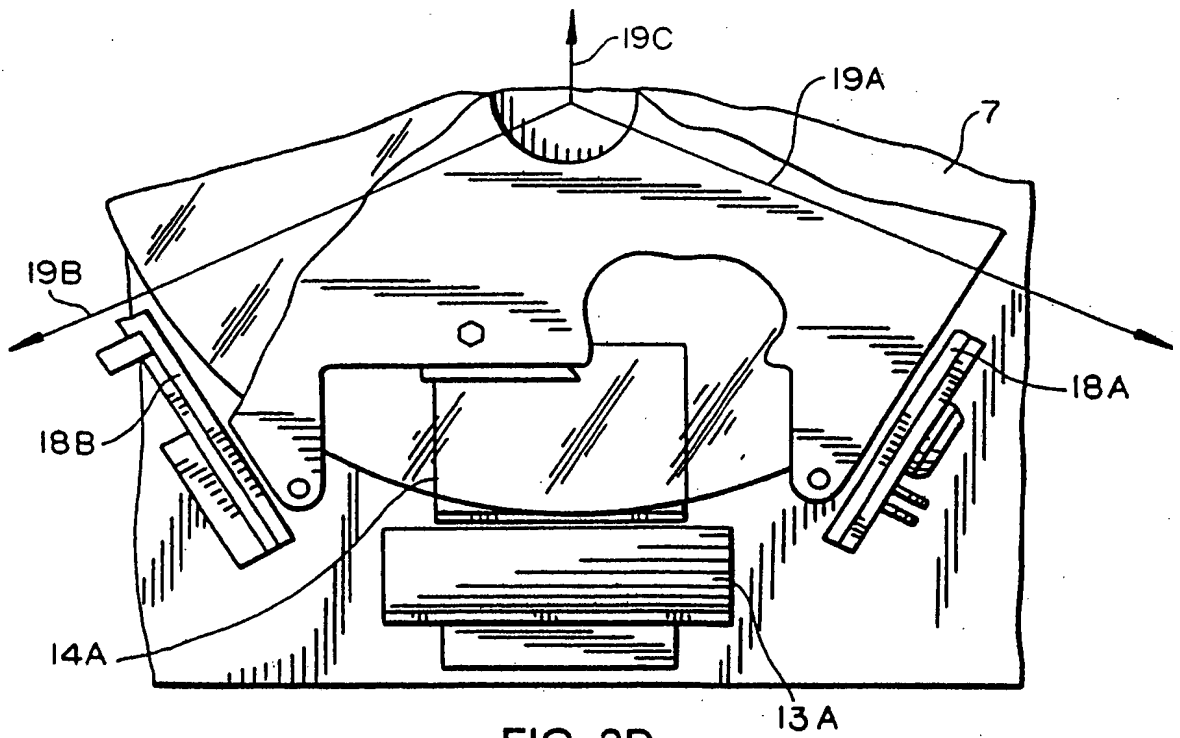


FIG. 2D

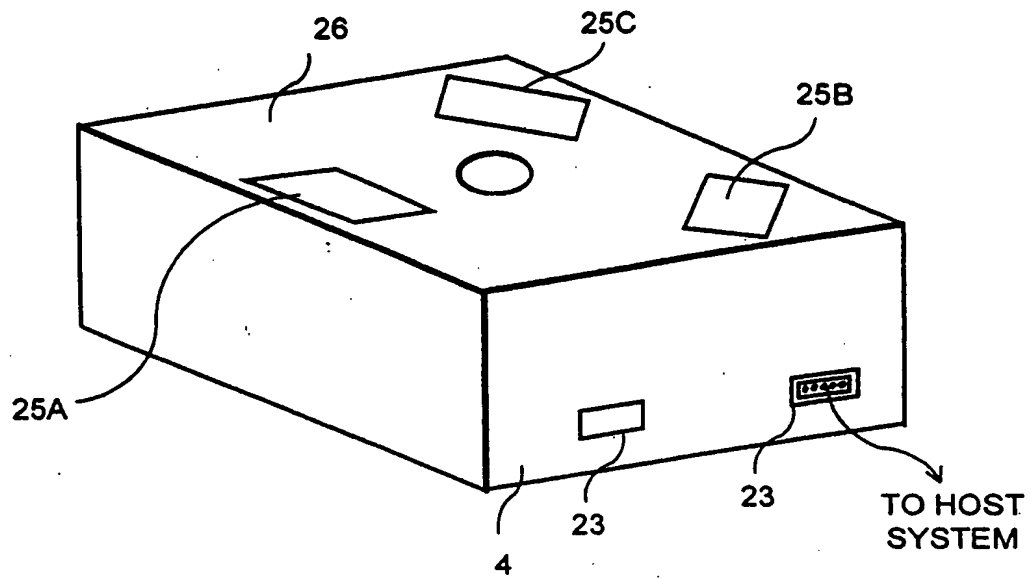


FIG. 2E

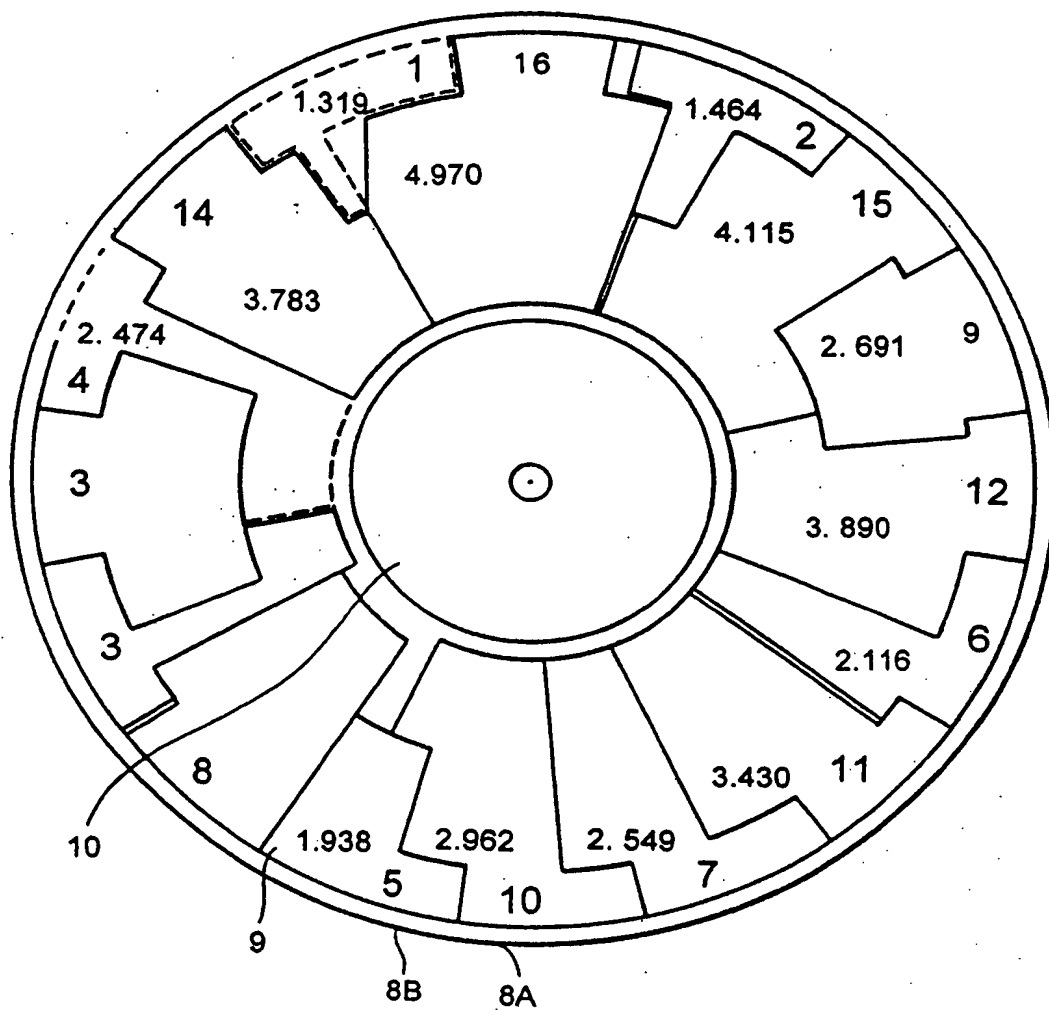


FIG. 3

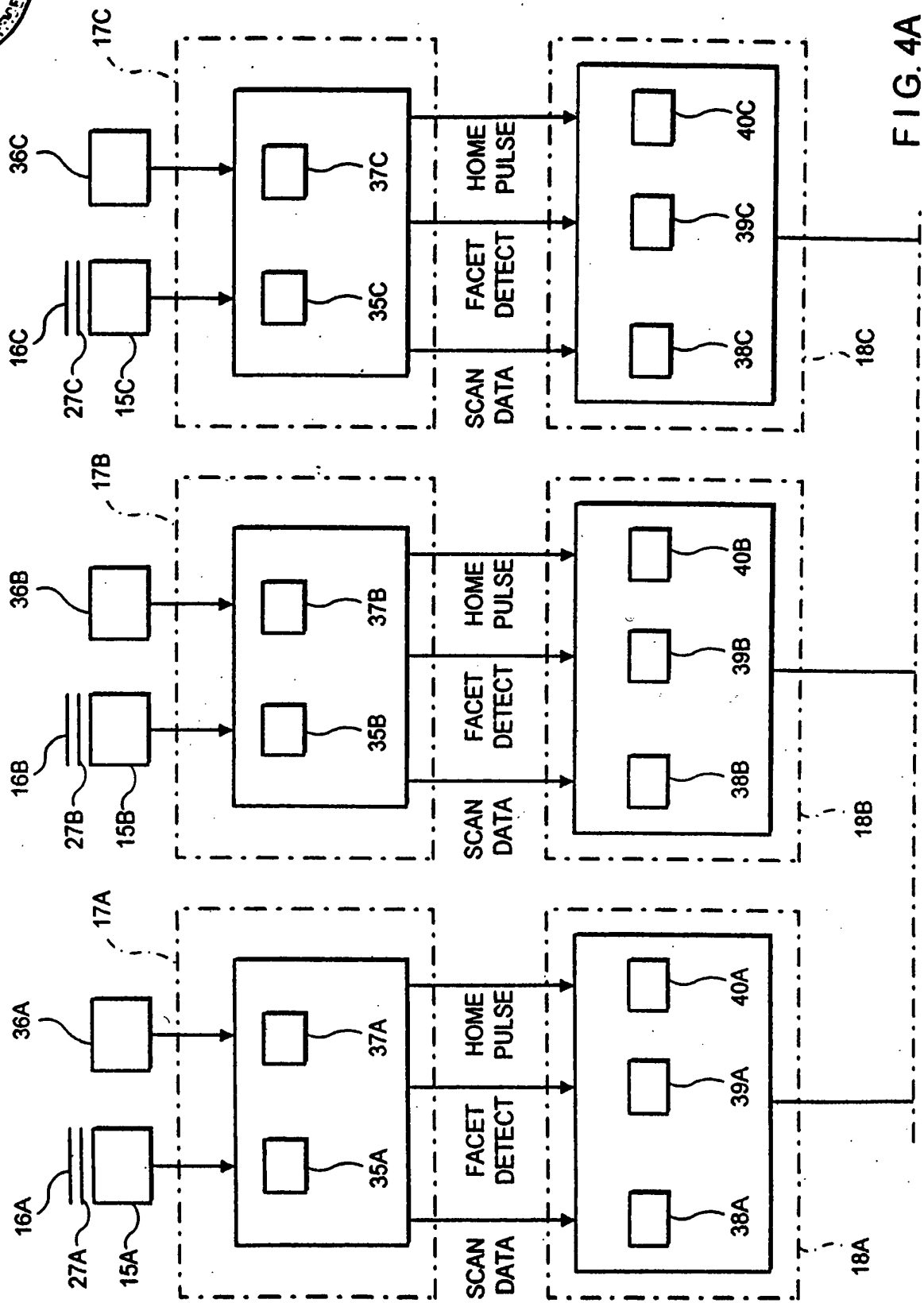


FIG. 4A

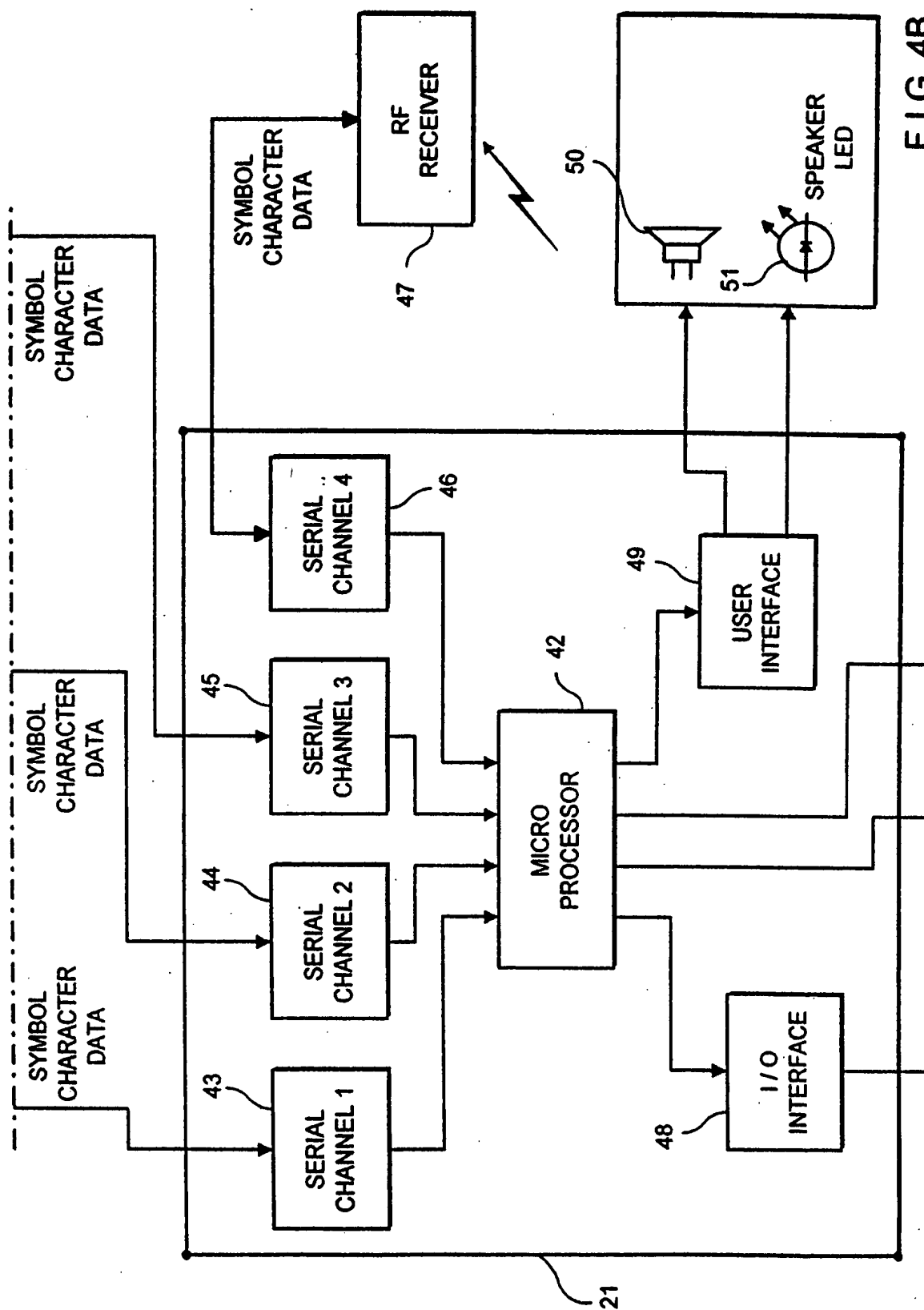


FIG. 4B

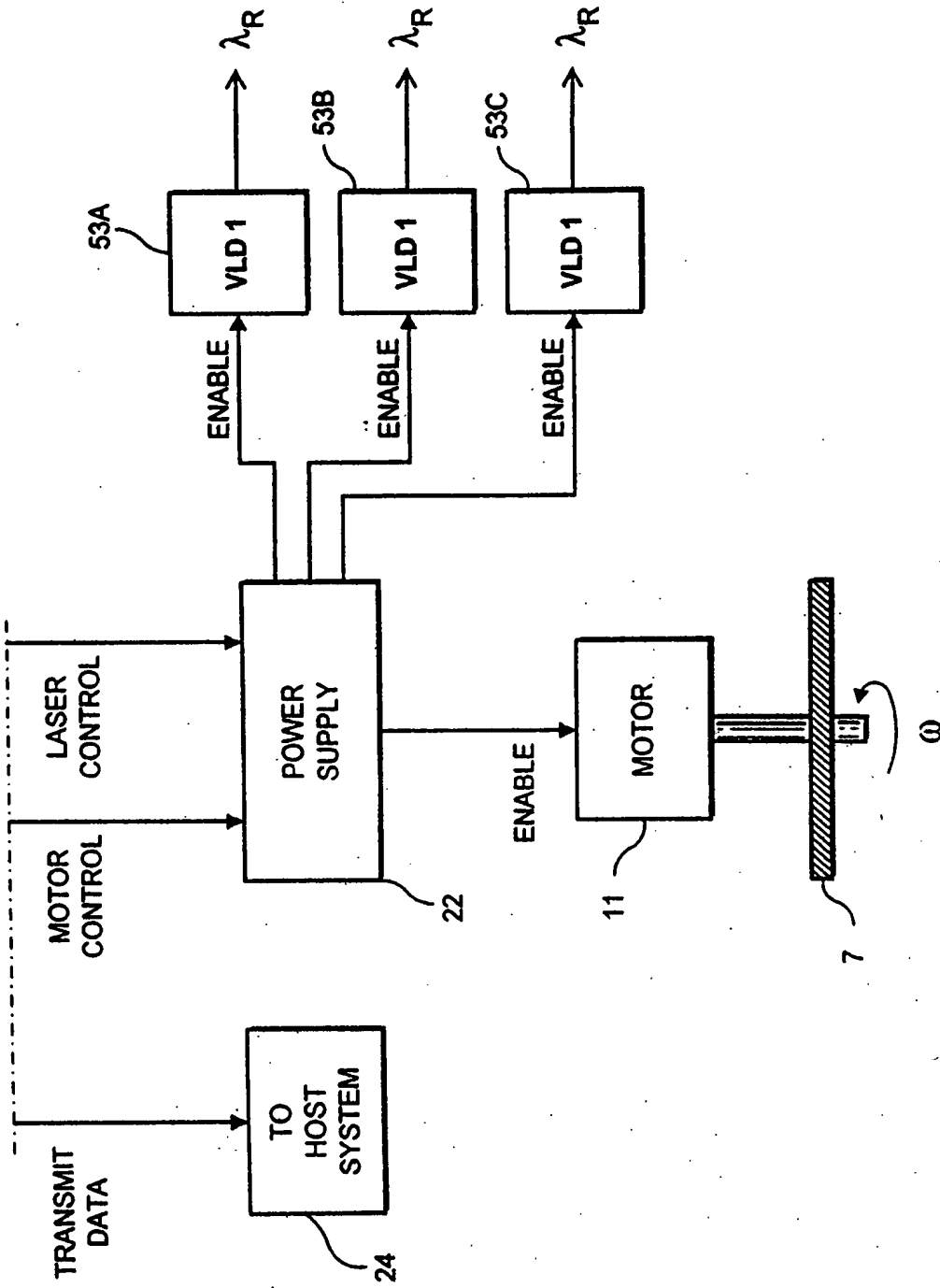


FIG. 4C



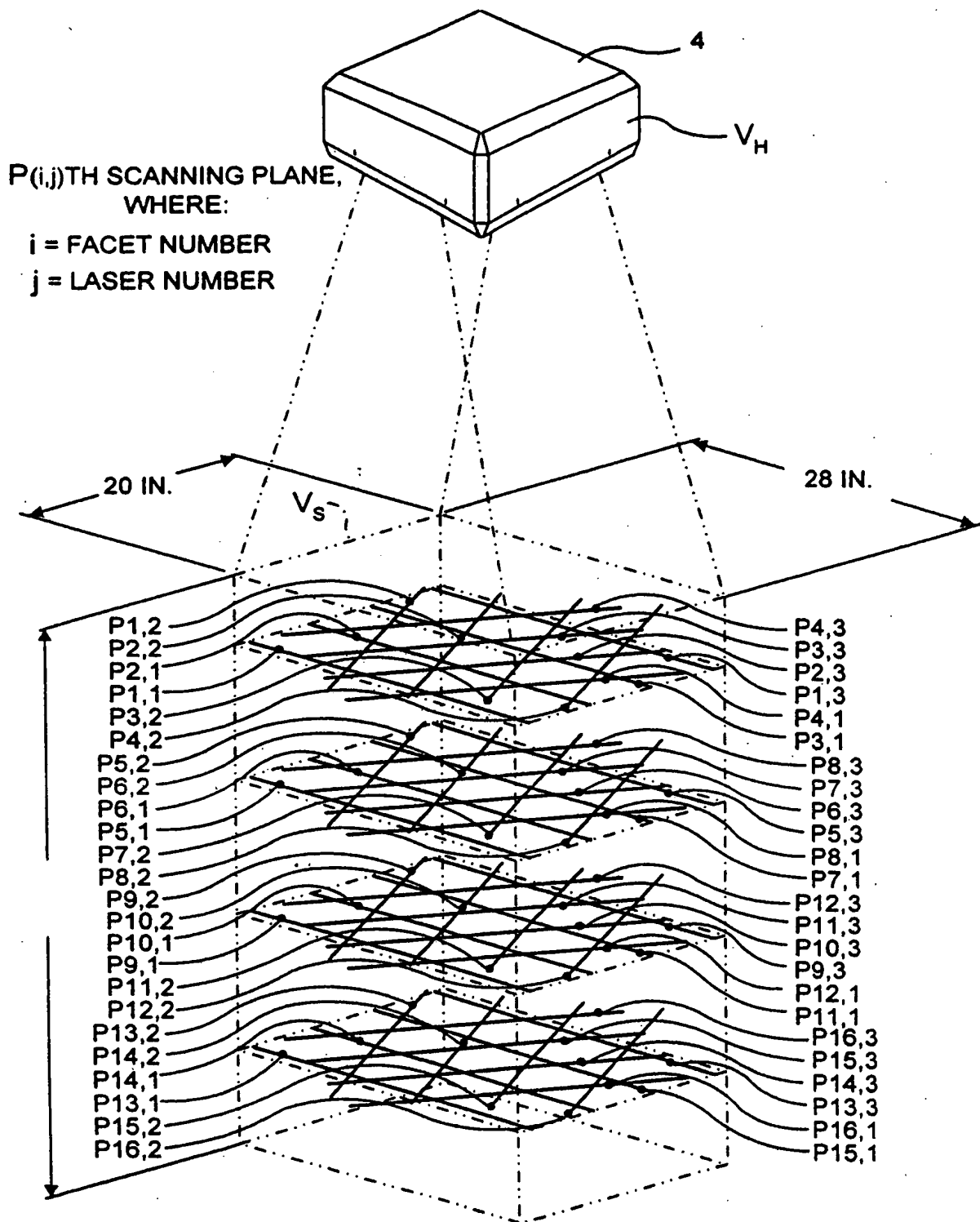
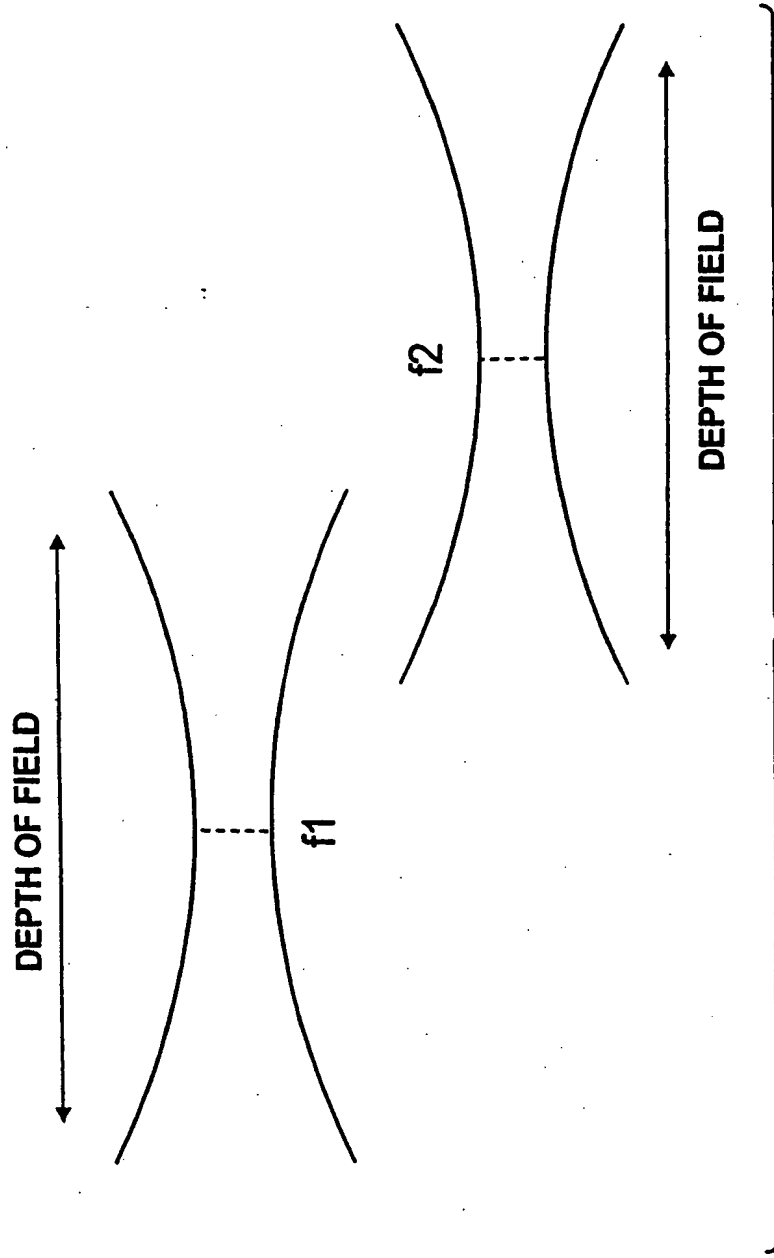


FIG. 5





# ADJACENT FOCAL REGIONS OF THE HOLOGRAPHIC DISC



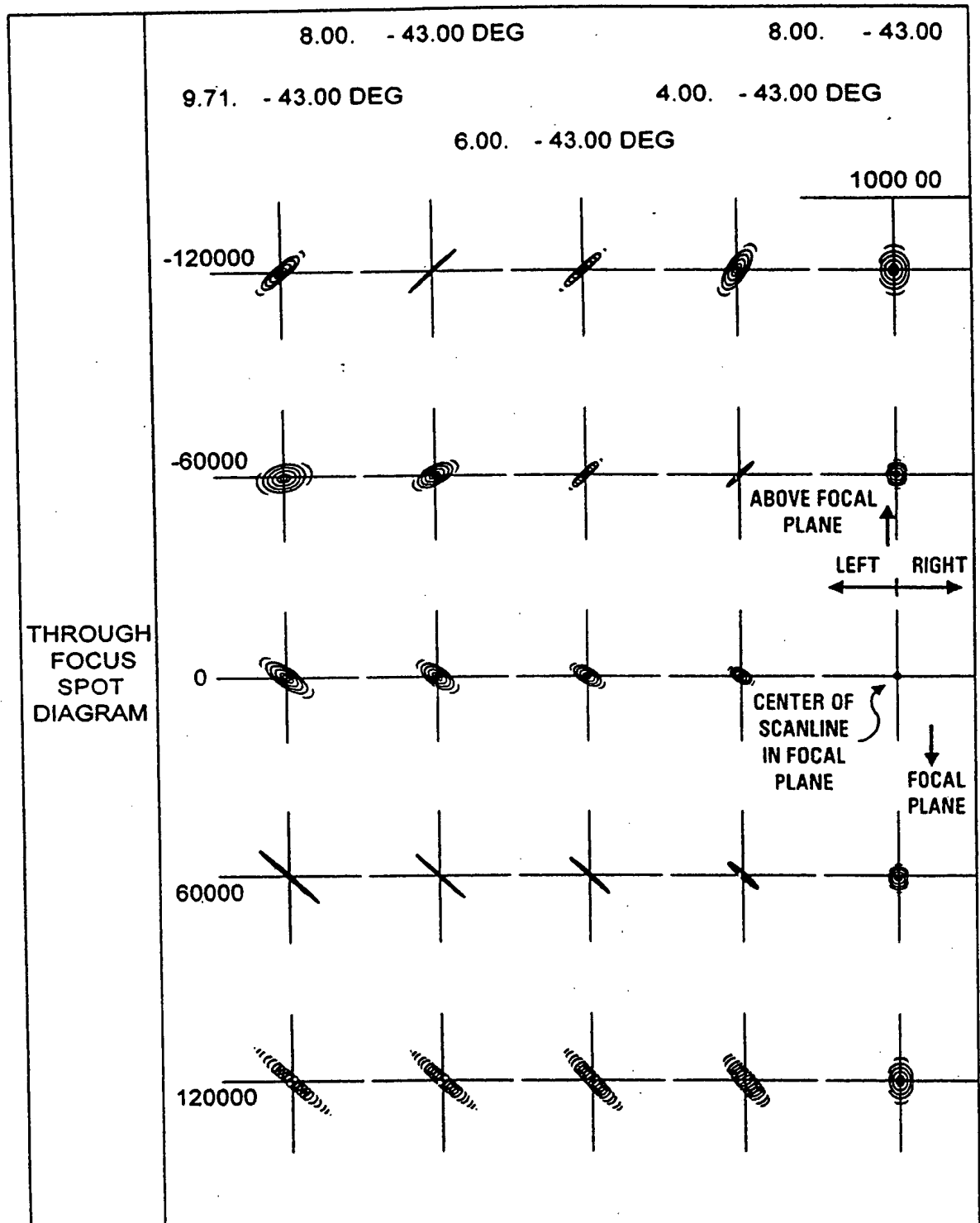


FIG. 6B

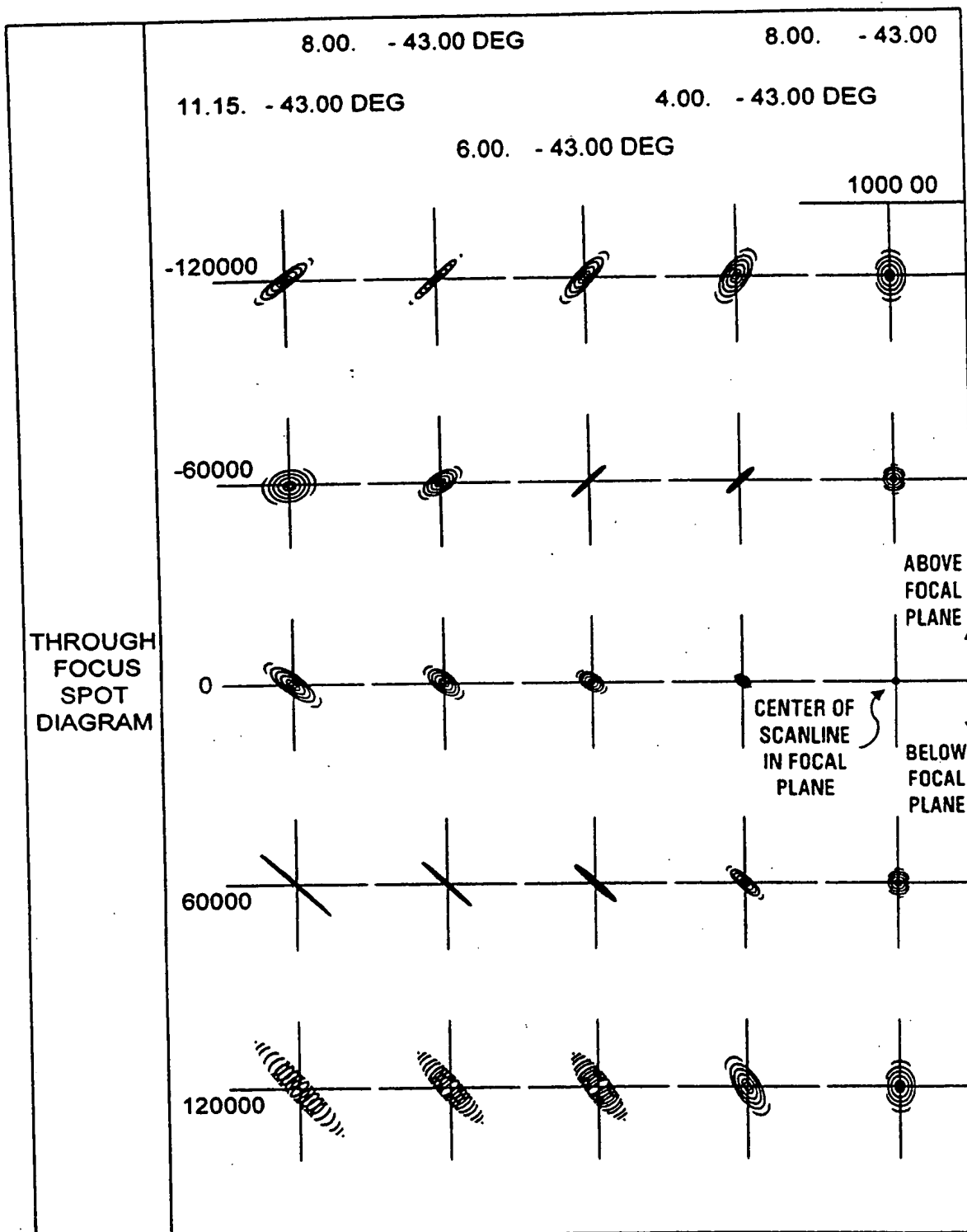


FIG. 6C

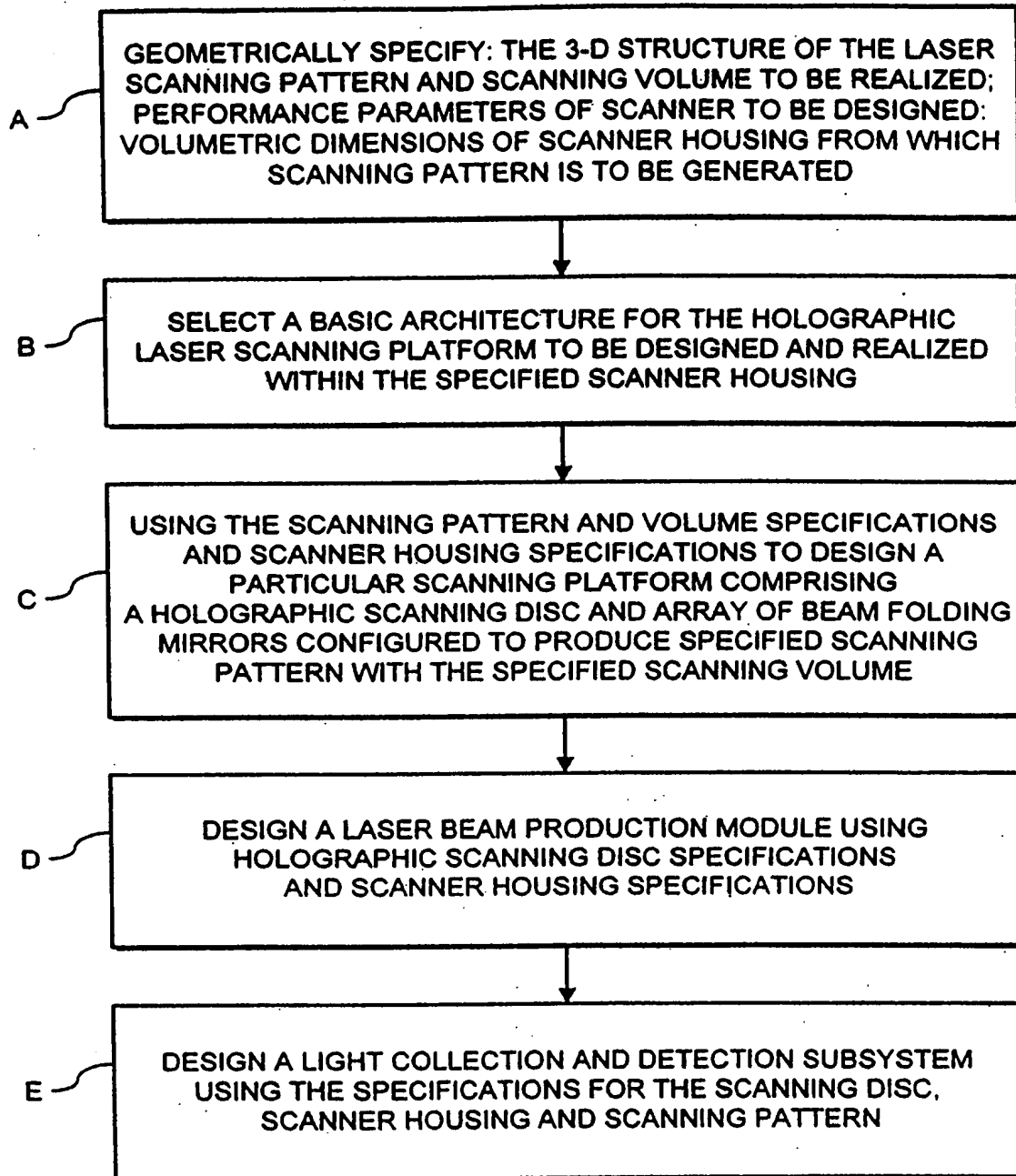
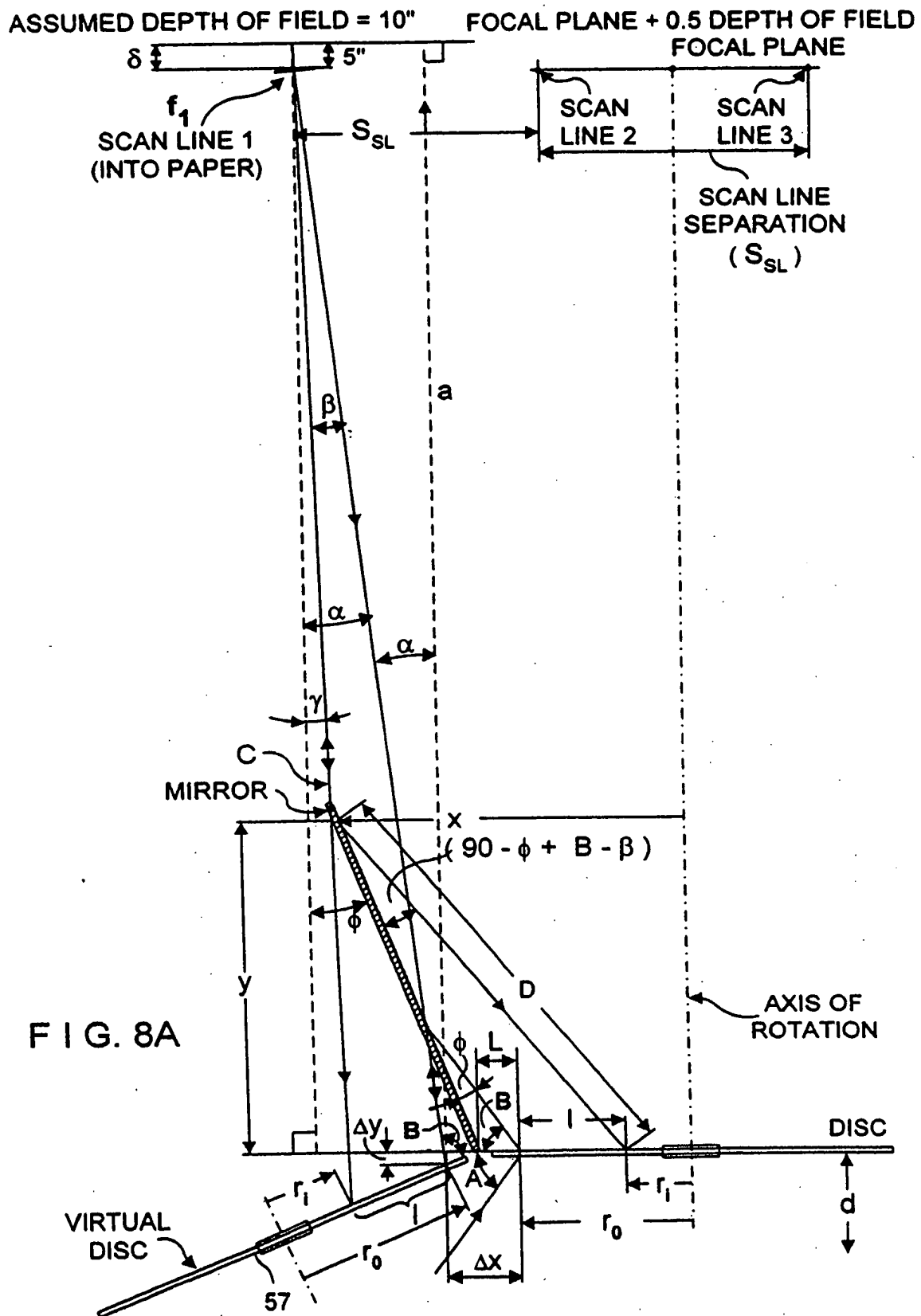


FIG. 7



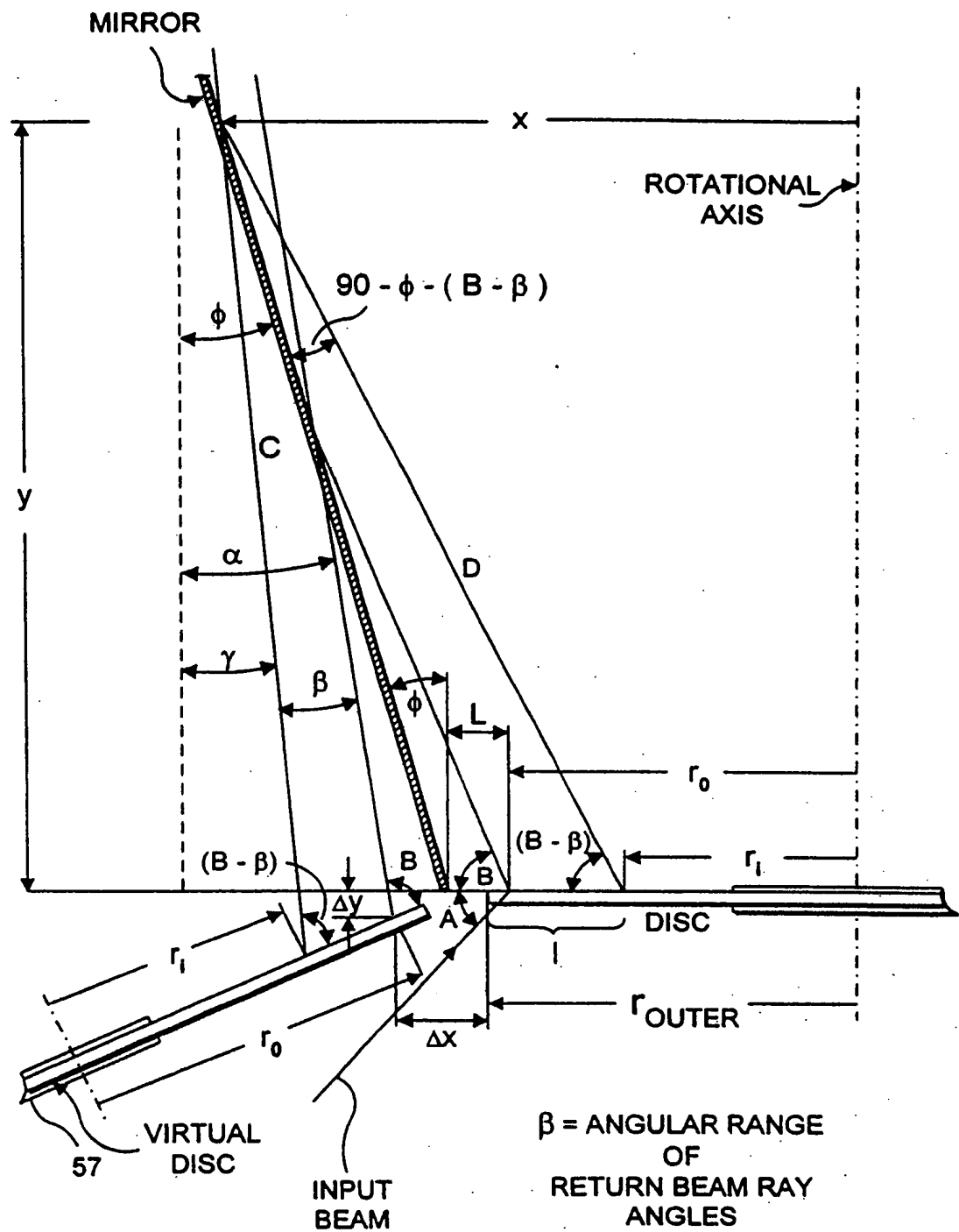
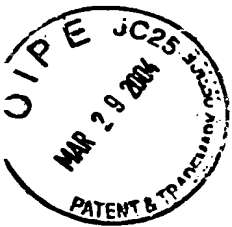


FIG. 8A1





( 1 ) THE RADIUS TO BEAM-INCIDENT-POINT ON THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $r_0$ "

( 2 ) SCANLINE SEPARATION BETWEEN ADJACENT SCANLINES AT THE FOCAL PLANE OF THE (i, J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $s_{sl}$ "

( 3 ) THE SCANLINE LENGTH (MEASURED INTO THE PAPER) FOR THE (i, J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $L_{sl}$ "

( 4 ) THE DISTANCE MEASURED FROM THE SCANNING DISC TO THE FOCAL PLANE OF THE (i, J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $a_i$ "

( 5 ) THE DISTANCE FROM RADIUS TO BEAM-INCIDENT-POINT  $r_0$  TO BEAM FOLDING MIRROR , ASSIGNED THE SYMBOLIC NOTATION " $L$ "

( 6 ) THE TILT ANGLE OF THE J-TH BEAM FOLDING MIRROR ASSOCIATED WITH GENERATION OF THE (i, J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $\phi_j$ "

( 7 ) THE TILT ANGLE OF THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $2\phi$ "

( 8 ) THE LATERAL SHIFT OF THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $\Delta X$ "

( 9 ) THE VERTICAL SHIFT OF THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $\Delta Y$ "

( 10 ) THE DISTANCE FROM THE ROTATION AXIS TO THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $r_0 + \Delta X$ "

( 11 ) THE DISTANCE FROM THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC TO THE FOCAL PLANE WITHIN WHICH THE (i, j)-TH SCANLINE RESIDES, ASSIGNED THE SYMBOLIC NOTATION " $f_i$ "

( 12 ) THE DIAMETER OF THE CROSS-SECTION OF THE LASER BEAM SCANNING STATION, ASSIGNED THE SYMBOLIC NOTATION " $d_{\text{BEAM}}$ "

( 13 ) THE ANGULAR GAP BETWEEN ADJACENT HOLOGRAPHIC SCANNING FACETS, ASSIGNED THE SYMBOLIC NOTATION " $d_{\text{GAP}}$ "

( 14 ) THE OUTER RADIUS OF THE AVAILABLE LIGHT COLLECTION REGION ON THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $r_{\text{OUTER}}$ "

FIG. 8B1



( 15 ) THE INNER RADIUS OF THE AVAILABLE LIGHT COLLECTION REGION ON THE HOLOGRAPHIC SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION " $r_{\text{INNER}}$ "

( 16 ) ONE-HALF OF THE DEPTH OF FIELD OF THE (i, j)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $\delta$ "

( 17 ) THE DISTANCE FROM THE MAXIMUM READ DISTANCE ( $f_i + 5$ ) TO THE INNER RADIUS  $r_i$  OF THE SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION "C"

( 18 ) THE OUTER RAY ANGLE MEASURED RELATIVE TO THE NORMAL TO THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $\alpha$ "

( 19 ) THE INNER RAY ANGLE MEASURED RELATIVE TO THE NORMAL TO THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $\gamma$ "

( 20 ) THE LIGHT COLLECTION ANGLE MEASURED FROM THE FOCAL POINT OF THE i-TH FACET TO THE LIGHT COLLECTION AREA OF THE SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION " $\beta$ "

( 21 ) THE INTERSECTION OF THE BEAM FOLDING MIRROR AND LINE C, ASSIGNED THE SYMBOLIC NOTATION "X"

( 21A ) THE INTERSECTION OF THE BEAM FOLDING MIRROR AND LINE C, ASSIGNED THE SYMBOLIC NOTATION "Y"

( 22 ) THE DISTANCE MEASURED FROM THE INNER RADIUS TO THE POINT OF MIRROR INTERSECTION, ASSIGNED THE SYMBOLIC NOTATION "D"

( 23 ) THE DISTANCE MEASURED FROM THE BASE OF THE SCANNER HOUSING TO THE TOP OF THE j -TH BEAM FOLDING MIRROR , ASSIGNED THE SYMBOLIC NOTATION "h"

( 24 ) THE DISTANCE MEASURED FROM THE SCANNING DISC TO THE BASE OF THE HOLOGRAPHIC SCANNER, ASSIGNED THE SYMBOLIC NOTATION "d"

( 25 ) THE FOCAL LENGHT OF THE i-TH HOLOGRAPHIC SCANNING FACET FROM THE SCANNING FACET TO THE CORRESPONDING FOCAL PLANE WITHIN THE SCANNING VOLUME, ASSIGNED THE SYMBOLIC NOTATION " $f_i$ "

( 26 ) INCIDENT BEAM ANGLE, ASSIGNED THE SYMBOLIC NOTATION " $A_i$ "

F I G. 8B2



- ( 27 ) DIFFRACTED BEAM ANGLE, ASSIGNED THE SYMBOLIC NOTATION " $B_i$ "
- ( 28 ) THE ANGLE OF THE J-TH LASER BEAM MEASURED FROM THE VERTICAL, ASSIGNED THE SYMBOLIC NOTATION " $\alpha$ "
- ( 29 ) THE SCAN ANGLE OF THE LASER BEAM , ASSIGNED THE SYMBOLIC NOTATION " $\theta_{si}$ "
- ( 30 ) THE SCAN MULTIPLICATION FACTOR FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $M_i$ "
- ( 31 ) THE FACET ROTATION ANGLE FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $\theta_{roti}$ "
- ( 32 ) ADJUSTED FACET ROTATION ANGLE ACCOUNTING FOR DEADTIME, ASSIGNED THE SYMBOLIC NOTATION " $\theta'_{roti}$ "
- ( 33 ) THE LIGHT COLLECTION EFFICIENCY FACTOR FOR THE i-TH HOLOGRAPHIC FACET, NORMALIZED RELATIVE TO THE 16TH FACET, ASSIGNED THE SYMBOLIC NOTATION " $\xi_i$ "
- ( 34 ) THE MAXIMUM LIGHT COLLECTION AREA FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $Area_i$ "
- ( 35 ) THE BEAM SPEED AT THE CENTER OF THE ( i, j )-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " $V_{center}$ "
- ( 36 ) THE ANGLE OF SKEW OF THE DIFFRACTED LASER BEAM AT THE CENTER OF THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " $\phi_{skew}$ "
- ( 37 ) THE MAXIMUM BEAM SPEED OF ALL LASER BEAMS PRODUCED BY THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $V_{max}$ "
- ( 38 ) THE MINIMUM BEAM SPEED OF ALL LASER BEAMS PRODUCED BY THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION " $V_{min}$ "
- ( 39 ) THE RATIO OF THE MAXIMUM BEAM SPEED TO THE MINIMUM BEAM SPEED, ASSIGNED THE SYMBOLIC NOTATION " $V_{max}/V_{min}$ "
- ( 40 ) THE DEVIATION OF THE LIGHT RAYS REFLECTED OFF THE PARABOLIC LIGHT REFLECTING MIRROR BENEATH THE SCANNING DISC, FROM THE BRAGG ANGLE FOR THE FACET, ASSIGNED THE SYMBOLIC NOTATION " $\delta_e$ "

FIG. 8B3



PARAMETER EQUATION USED IN THE SPREADSHEET  
DESIGN OF THE SCANNER

$$(1) \Delta x := L (1 + \cos (2 \phi))$$

$$(2) \Delta y := L \sin (2 \phi)$$

$$(3) \Delta y := r_0 + \Delta x$$

$$(4) C := \sqrt{(f + \delta)^2 + l^2 + 2(f + \delta)l \cos(B)}$$

LAW OF COSINES, WHERE:  $l = r_{\text{outer}} - r_{\text{inner}}$

$$\beta = \alpha - \gamma = B + 2\phi - 90 - \gamma$$

$$(5) \alpha := B - 90 + 2\phi$$

$$(6) r := \alpha - \cos \left[ \frac{(f + \delta)^2 + C^2 - l^2}{2(f + \delta)C} \right]$$

$$(7) \beta := \alpha - \gamma$$

$$(8) X := D \cos (B - \beta) + r_i$$

$$(9) Y := D \sin (B - \beta)$$

$$(10) D := \frac{[r_0 + L - r_i] \sin (90 + \phi)}{\sin (90 - B + \beta - \phi)} \quad (\text{LAW OF SINES})$$

$$(11) h := Y + d$$

FIG. 8C1



$$(12) f_i := \sqrt{a_i^2 + [m S_{SL} [r_0 + \Delta x]]^2}$$

$m$  IS A FACTOR THAT VARIES FROM SCAN LINE TO SCAN LINE AND IS DETERMINED BY SCAN LINE SEPARATION AND DISTANCE FROM THE ROTATIONAL AXIS OF THE DISC.

$$(13) B_i := \text{atan} \left[ \left[ \frac{m S_{SL} [r_0 + \Delta x]}{a_i} \right] \right] + 90 - 2\phi$$

$$\left\{ \begin{array}{l} (14) \theta_{Si} := 2 \text{atan} \left[ \left[ \frac{\frac{1}{2} \text{ScanLineLength}}{f_i} \right] \right] \\ (15) M_i := \frac{r_0}{f_i} + \cos(\lambda_i) + \cos(B_i) \\ (16) \theta_{roti} := \frac{\theta_{Si}}{M_i} \end{array} \right.$$

$$(17) \theta'_{roti} := \theta_{roti} + \underbrace{\frac{d_{beam}}{r_0} + \frac{d_{gap}}{r_0}}_{\Theta_{dead}}$$

$$(18) \xi_i := \left[ \frac{f_i}{f_{16}} \right]^2 \frac{\sin[B_{16}]}{\sin(B_i)} H_i$$

$$(19) \text{Area}_i := \pi \left[ r_{outer}^2 + r_{inner}^2 \right] \frac{\xi_i}{\sum_{i=1}^{16} [\xi_i]} \quad i = 1, 2, \dots, 16$$

FIG. 8C2

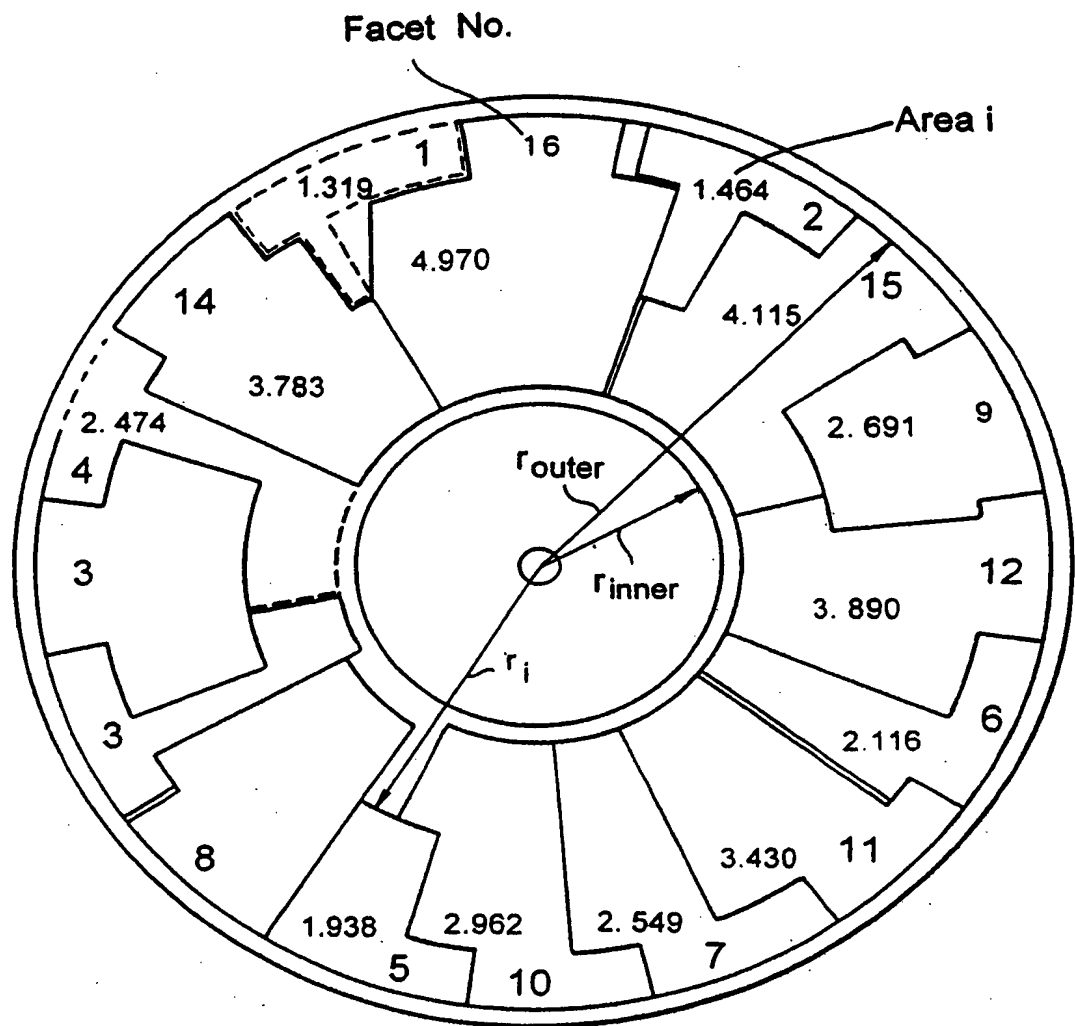


FIG. 9



# GEOMETRICAL OPTICS MODEL FOR HOLOGRAPHIC ( TOTAL OUT AND BACK ) LIGHT DIFFRACTION EFFICIENCY CALCULATIONS

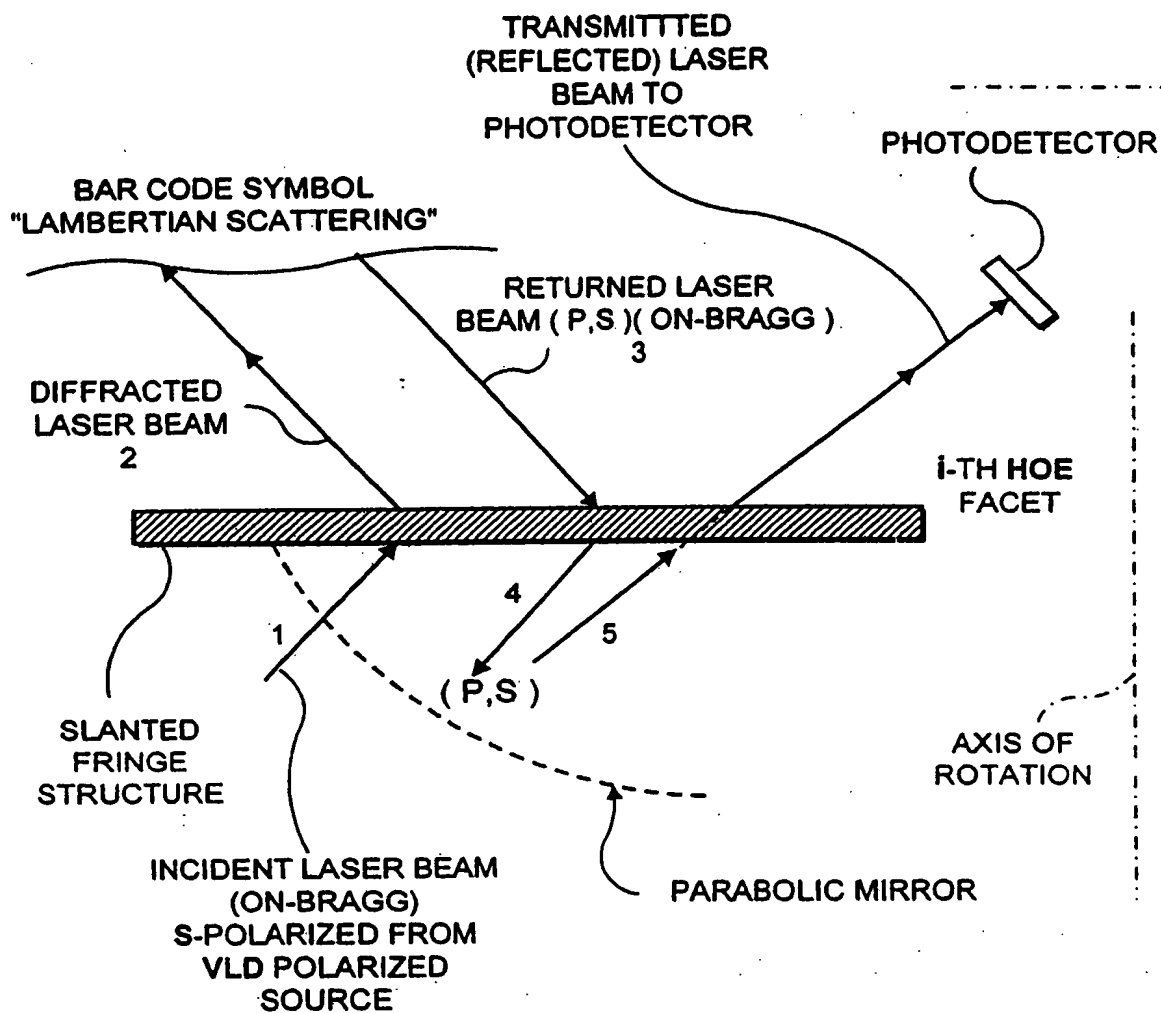


FIG. 10A1

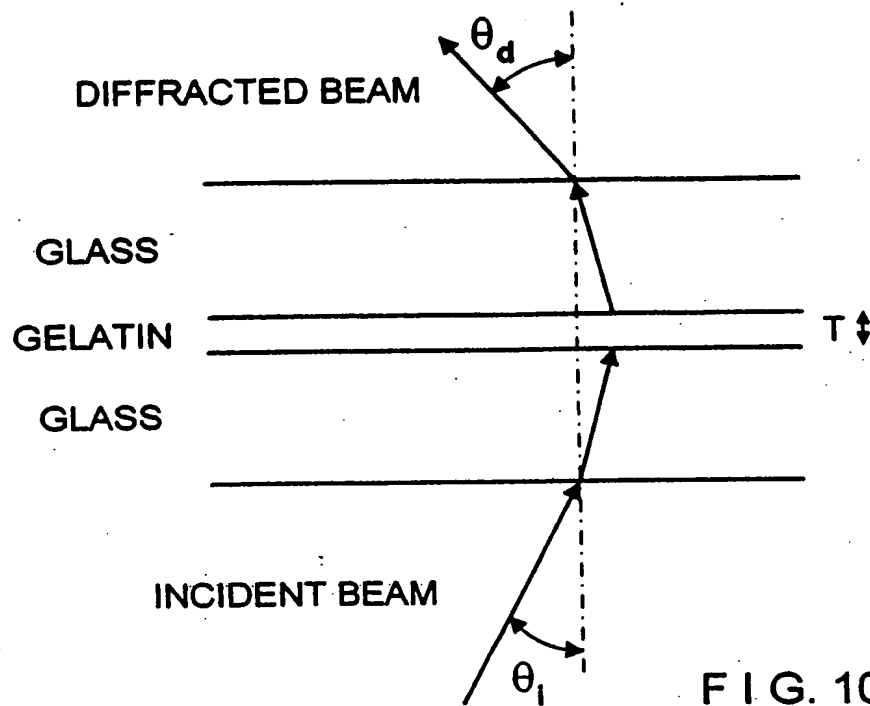


FIG. 10A2

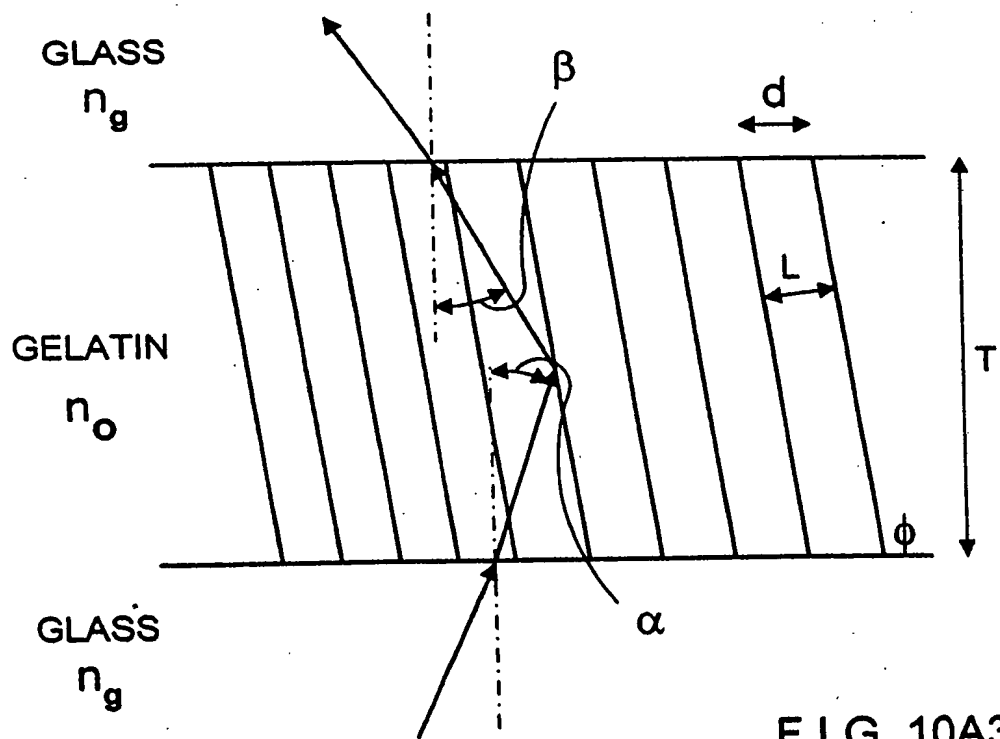


FIG. 10A3





SCANNING DISC ANALYSIS INCLUDING FRESNEL LOSSES AND ESTIMATED INTERNAL LOSSES OF 10% .THE 10% LOSS INCLUDES ABOUT 8% SCATTERING AND ABSORPTION AND ABOUT 2% FRESNEL LOSSES AT THE DCG/GLASS INTERFACES

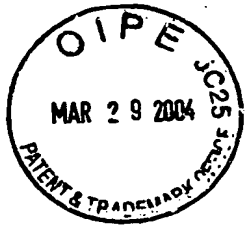
S AND P POLARIZATION DIFFRACTION EFFICIENCIES FOR THE MOST GENERAL CASE

S AND P DIFFRACTION EFFICIENCIES AT THE BRAGG ANGLE AS A FUNCTION OF  $n_1$ , THE  $\delta n$  OF THE HOLOGRAPHIC MEDIUM. SLANTED FRINGES AND EXTERNAL ANGLES ARE INCLUDED. THIS IS A GENERALIZATION OF THE MORE COMMON CASE OF ZERO SLANT.  $\delta n$  ( $n_1$ ) IS IN STEPS OF 0.001 microns.

DEFINITIONS:

- $\theta_i$  = ANGLE OF INCIDENCE (EXTERNAL) ( $\theta_i = 90^\circ - A_i$ )
- $\alpha$  = ANGLE OF INCIDENCE (INTERNAL)
- $\theta_d$  = ANGLE OF DIFFRACTION (EXTERNAL) ( $\theta_d = 90^\circ - B_i$ )
- $\beta$  = ANGLE OF DIFFRACTION (INTERNAL)
- $\delta$  = DEVIATION FROM THE BRAGG ANGLE
- $\phi$  = TILT OF BRAGG PLANES  
=  $\pi/2$  FOR NO TILT
- $L$  = SEPARATION OF THE BRAGG PLANES
- $T$  = THICKNESS OF HOE MEDIUM
- $d$  = EXTERNAL FRINGE SPACING
- $n_g$  = REFRACTIVE INDEX OF THE GLASS SUBSTRATE
- $n_0$  = AVERAGE REFRACTIVE INDEX OF THE HOE MEDIUM
- $\Delta n_1$  =  $\delta n$  OF HOE FRINGE STRUCTURE
- $\lambda_a$  = WAVELENGTH IN AIR
- $\delta\lambda$  = DEVIATION FROM  $\lambda_a$  (BRAGG  $\lambda$  )

FIG. 10B



FIXED, OR ESTABLISHED PARAMETERS:

$n_0, \Delta n_1, \theta_i, \theta_d, \delta, \delta\lambda, \lambda_a, T.$

$$n_0 := 1.4$$

$$n_g := 1.515$$

$$\text{deg} = \frac{\pi}{180}$$

$$\Delta n_1 := 0, .001, \dots, .2$$

$$\theta_i := 43 \text{ deg}$$

$$\theta_d := 26.6 \text{ deg}$$

$$\delta := 0 \text{ deg}$$

$$\delta_\lambda := 0$$

$$T := 2.2$$

$$\lambda_a := .670$$

F I G. 10B1



$$(1) \alpha := \text{asin} \left[ \frac{\sin [\theta_i]}{n_0} \right]$$

$$(2) \beta := \text{asin} \left[ \frac{\sin [\theta_d]}{n_0} \right]$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta - \alpha}{2}$$

$$(4) d := \frac{\lambda_a}{\sin [\theta_i] + \sin [\theta_d]}$$

GRATING  
EQUATION

$$(5) L := d \sin (\phi)$$

$$(6) C_R := \cos (\alpha)$$

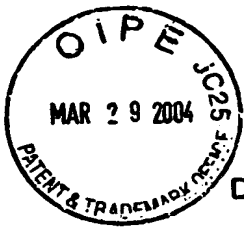
$$(7) C_S := \cos (\alpha) - \frac{\lambda_a}{n_0 L} \cos (\phi)$$

$$(8) N[n_1] := \pi n_1 \frac{T}{\lambda_a \sqrt{C_R C_S}}$$

$$(9) \Gamma := 2 \pi \delta \frac{\sin (\phi - \alpha)}{L} - \delta_\lambda \frac{\pi}{n_0 L^2}$$

$$(10) S[n_1] := \Gamma \frac{T}{2 C_S}$$

FIG. 10C1



DIFFRACTION EFFICIENCIES:  $E_s$  AND  $E_p$  ( INCLUDING FRESNEL REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10% )  
 ASSUMING  $n$  - glass = 1.5155 AND ANGLES AS GIVEN BELOW:

$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 26.6 \text{ deg}$$

$$(11) \quad E_s[n_1] := \frac{\left[ \sin \left[ \sqrt{N[n_1]^2 + S[n_1]^2} \right] \right]^2}{1 + \frac{S[n_1]^2}{N[n_1]^2}} t_s(1-.1)$$

$$(12) \quad E_p[n_1] := \frac{\left[ \sin \left[ \sqrt{[N[n_1] \cos(2(\alpha - \phi))]^2 + S[n_1]^2} \right] \right]^2}{1 + \frac{S[n_1]^2}{[N[n_1] \cos(2(\alpha - \phi))]^2}} t_p(1-.1)$$

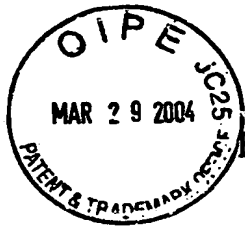
$$(13) \quad T_s[n_1] := E_s[n_1] \cdot \frac{E_s[n_1] + E_p[n_1]}{2}$$

POLARIZED INCIDENT BEAM ↘ ↖ RETURN BEAM

( $T_s$  IS THE TOTAL OUT-AND-BACK DIFFRACTION EFFICIENCY FOR AN S-POLARIZED OUTGOING BEAM INCIDENT ON THE DISC . INCLUDES FRESNEL REFLECTION LOSSES AND INTERNAL LOSSES OF 10%)

$$(14) \quad H_i(\Delta n) := \frac{T_{s16}(\Delta n)}{T_{s1}(\Delta n)}$$

FIG. 10C2



# PARAMETERS FOR CALCULATING THE FRESNEL REFLECTION LOSSES AND TRANSMISSION

$$(15) \theta_{r,1} := \text{asin} \left[ \frac{\sin [\theta_i]}{n_g} \right]$$

$$(16) \theta_{r,2} := \text{asin} \left[ \frac{\sin [\theta_d]}{n_g} \right]$$

$$(17) R_{s,1} := \left[ \frac{\sin [\theta_i - \theta_{r,1}]}{\sin [\theta_i + \theta_{r,1}]} \right]^2 \quad \begin{array}{l} \text{S-POLARIZATION} \\ \text{REFLECTION} \\ \text{AT FIRST (ENTRY )} \\ \text{SURFACE OF DISC} \end{array}$$

$$(18) R_{s,2} := \left[ \frac{\sin [\theta_d - \theta_{r,2}]}{\sin [\theta_d + \theta_{r,2}]} \right]^2 \quad \begin{array}{l} \text{S-POLARIZATION} \\ \text{REFLECTION} \\ \text{AT SECOND (EXIT )} \\ \text{SURFACE OF DISC} \end{array}$$

$$(19) R_{p,1} := \left[ \frac{\tan [\theta_i - \theta_{r,1}]}{\tan [\theta_i + \theta_{r,1}]} \right]^2 \quad \begin{array}{l} \text{P-POLARIZATION} \\ \text{REFLECTION} \\ \text{AT FIRST (ENTRY )} \\ \text{SURFACE OF DISC} \end{array}$$

$$(20) R_{p,2} := \left[ \frac{\tan [\theta_d - \theta_{r,2}]}{\tan [\theta_d + \theta_{r,2}]} \right]^2 \quad \begin{array}{l} \text{P-POLARIZATION} \\ \text{REFLECTION} \\ \text{AT SECOND (EXIT )} \\ \text{SURFACE OF DISC} \end{array}$$

## BOTH SURFACES

$$(21) t_s := [1 - R_{s,1}] \cdot [1 - R_{s,2}] \quad \begin{array}{l} \text{S-POLARIZED} \\ \text{FRESNEL TRANSMISSION} \end{array}$$

$$(22) t_p := [1 - R_{p,1}] \cdot [1 - R_{p,2}] \quad \begin{array}{l} \text{P-POLARIZED} \\ \text{FRESNEL TRANSMISSION} \end{array}$$

FIG. 10D



# FACET No. 1

DIFFRACTION EFFICIENCIES:  $E_s$ ,  $E_p$ ,  $T_s$  - INCLUDING FRESNEL REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10%.  
(ASSUMING  $n$  GLASS = 1.515 AND ANGLES ARE AS GIVEN BELOW)

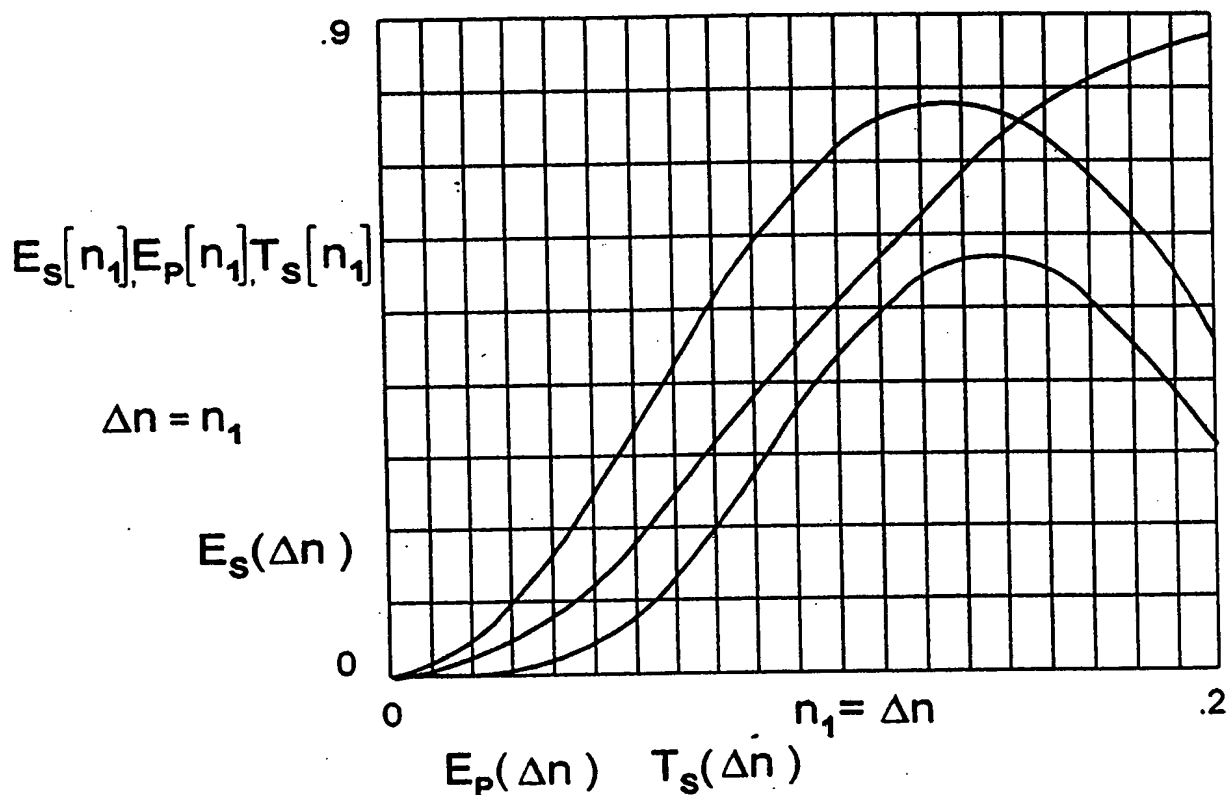
$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 26.6 \text{ deg}$$

$$n_0 = 1.4$$

$$T = 2.2 \text{ microns}$$

$$\lambda_a = 0.67$$



$$\text{FOR: } n_1 := .146$$

$$E_s[n_1] = 0.769$$

$$E_p[n_1] = 0.694$$

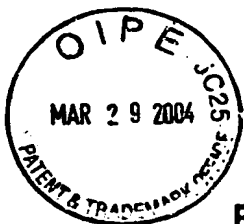
$$T_s[n_1] = 0.562$$

$$H_1 := \frac{0.474}{T_s[n_1]}$$

$$H_1 = 0.843$$

H.1 IS THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 1 RELATIVE TO THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 16

FIG. 10E1



DIFFRACTION EFFICIENCIES:  $E_s$ ,  $E_p$ ,  $T_s$  - INCLUDING FRESNEL REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10%. (ASSUMING  $n$  GLASS = 1.515 AND ANGLES ARE AS GIVEN BELOW)

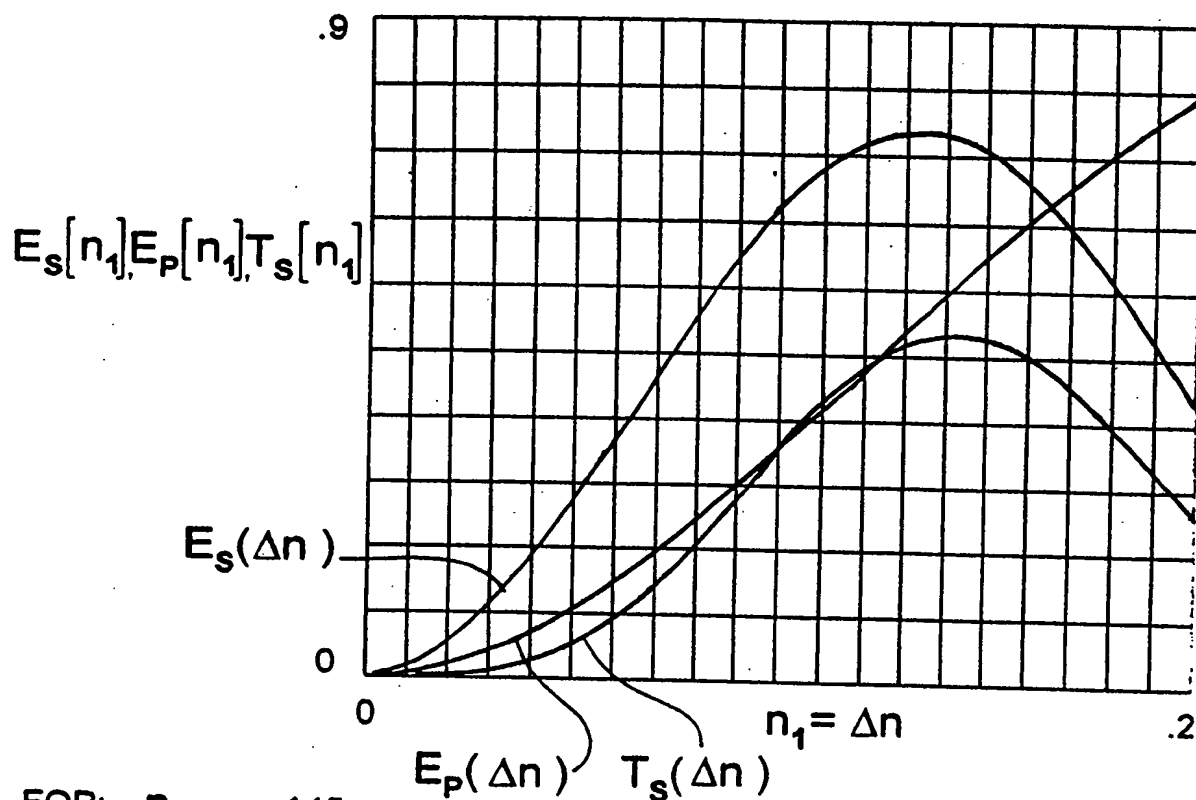
$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 41.8 \text{ deg}$$

$$n_0 = 1.4$$

$$T = 2.2 \text{ microns}$$

$$\lambda_a = 0.67$$



FOR:  $n_1 := .145$

$$E_s[n_1] = 0.736$$

$$E_p[n_1] = 0.552$$

$$T_s[n_1] = 0.474$$

$$H_{16} := \frac{0.474}{T_s[n_1]}$$

$$H_{16} = 1$$

H.16 IS THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 16 RELATIVE TO THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 1

FIG. 10E2



# GEOMETRICAL OPTICS MODEL FOR HOLOGRAPHIC ( TOTAL OUT AND BACK ) LIGHT DIFFRACTION EFFICIENCY CALCULATIONS

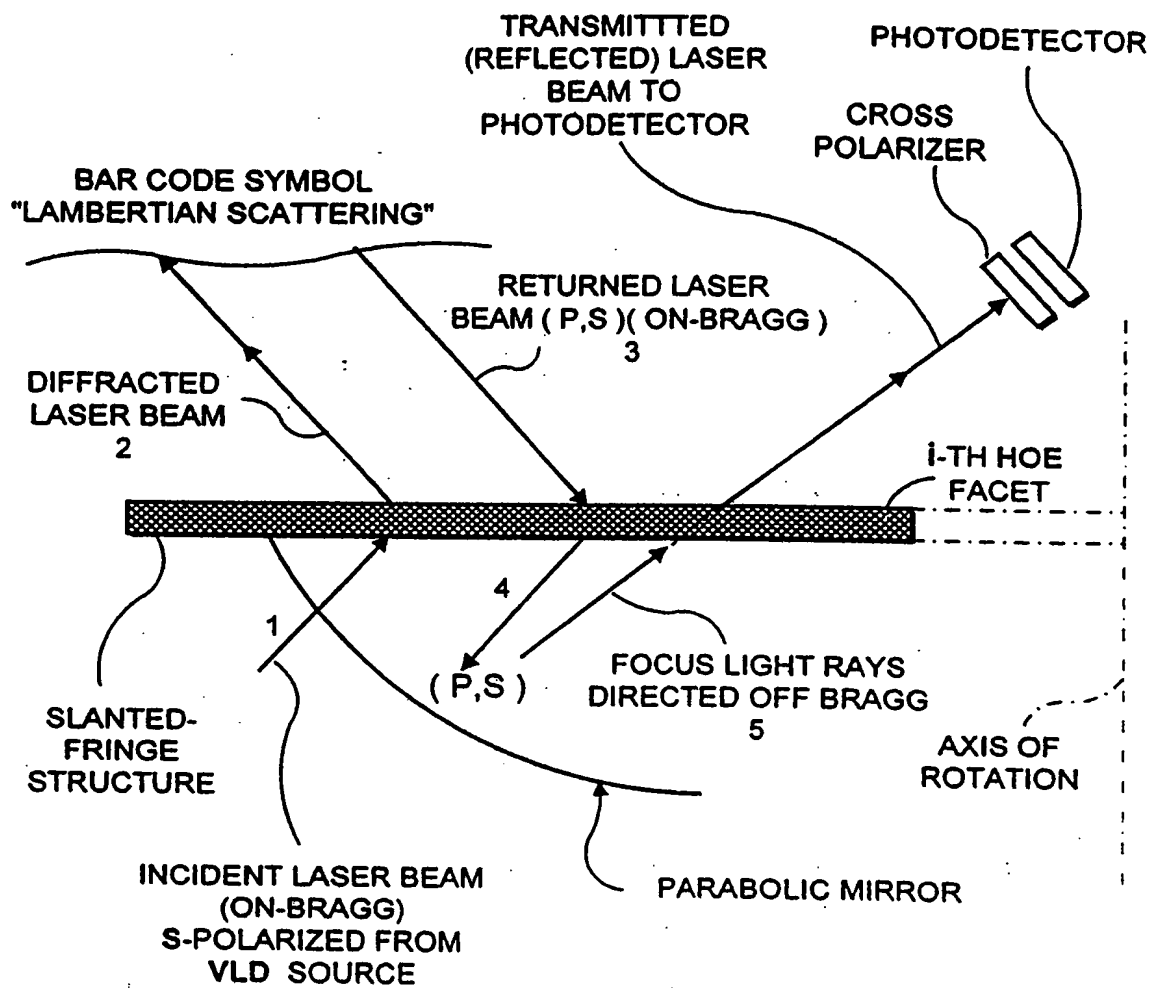


FIG. 10F



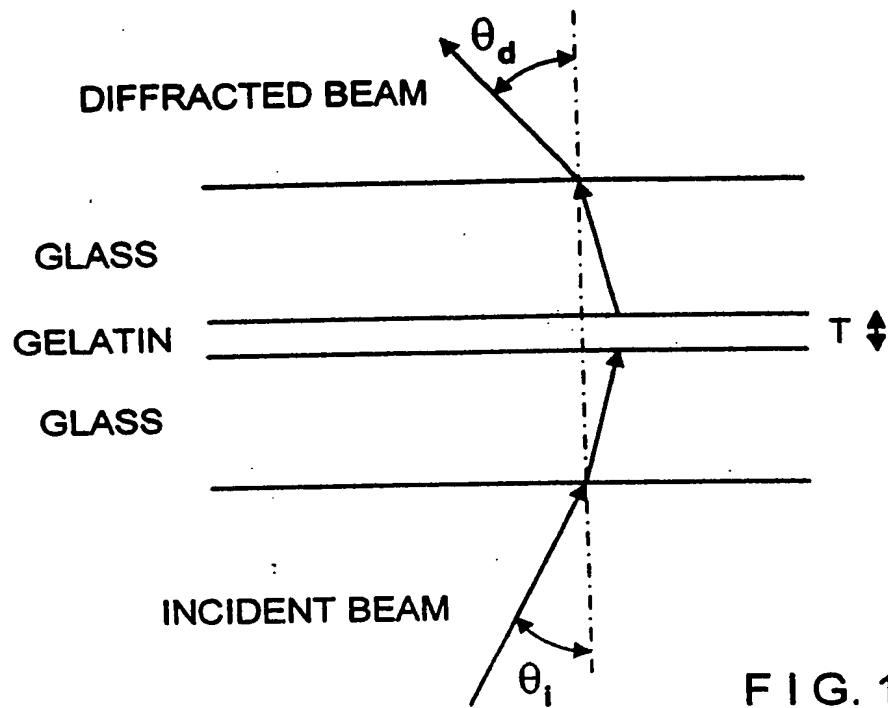


FIG. 10F1

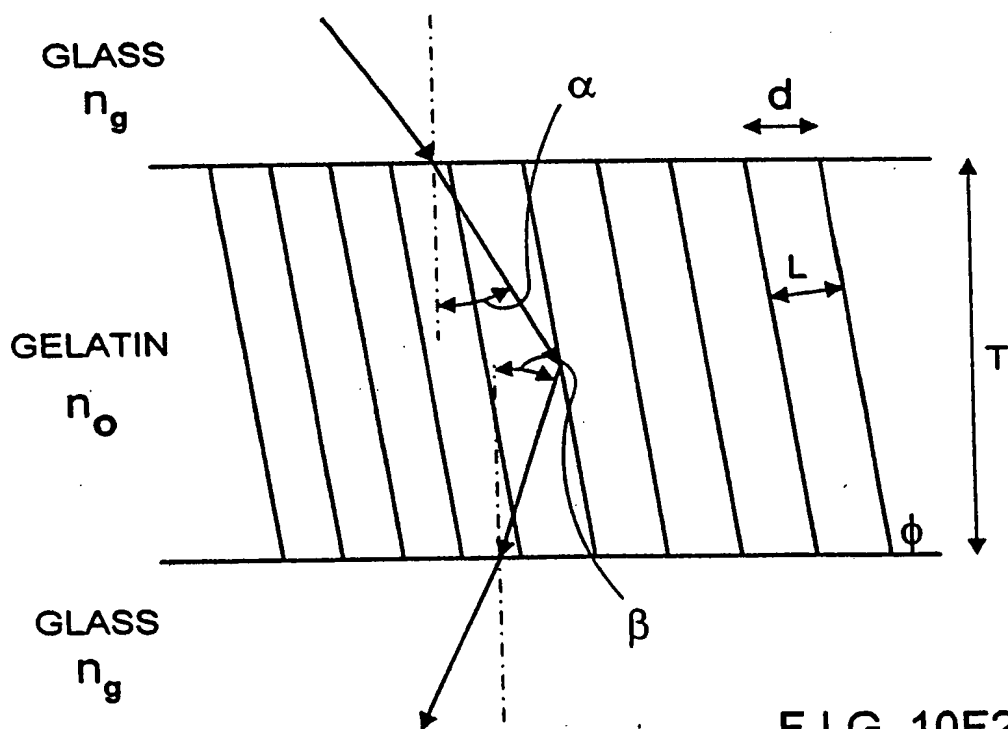


FIG. 10F2



SCANNING DISC ANALYSIS INCLUDING FRESNEL LOSSES AND  
ESTIMATED INTERNAL LOSSES OF 10% .THE 10% LOSS INCLUDES  
ABOUT 8% SCATTERING AND ABSORPTION AND ABOUT 2%  
FRESNEL LOSSES AT THE DCG/GLASS INTERFACES

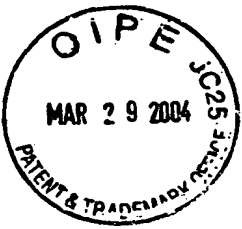
S AND P POLARIZATION DIFFRACTION EFFICIENCIES FOR MOST GENERAL  
CASE

S AND P DIFFRACTION EFFICIENCIES AT THE BRAGG ANGLE AS A FUNCTION  
OF  $n_1$  AND  $\delta n$  OF THE HOLOGRAPHIC MEDIUM. SLANTED FRINGES AND  
EXTERNAL ANGLES ARE INCLUDED. THIS IS A GENERALIZATION OF THE MORE  
COMMON CASE OF ZERO SLANT.  $\delta n$  ( $n_1$ ) IS IN STEPS OF 0.001 microns.

DEFINITIONS:

- $\theta_i$  = ANGLE OF INCIDENCE (EXTERNAL) ( $\theta_i = 90^\circ - A_i$ )
- $\alpha$  = ANGLE OF INCIDENCE (INTERNAL)
- $\theta_d$  = ANGLE OF DIFFRACTION (EXTERNAL) ( $\theta_d = 90^\circ - B_i$ )
- $\beta$  = ANGLE OF DIFFRACTION (INTERNAL)
- $\delta$  = DEVIATION FROM THE BRAGG ANGLE
- $\phi$  = TILT OF BRAGG PLANES
- $\phi = \pi/2$  FOR NO TILT
- $L$  = SEPARATION OF THE BRAGG PLANES
- $T$  = THICKNESS OF HOE MEDIUM
- $d$  = EXTERNAL FRINGE SPACING
- $n_g$  = REFRACTIVE INDEX OF THE GLASS SUBSTRATE
- $n_0$  = AVERAGE REFRACTIVE INDEX OF THE HOE MEDIUM
- $n_1$  =  $\delta n$  OF HOE FRINGE STRUCTURE
- $\lambda_a$  = WAVELENGTH IN AIR
- $\delta\lambda$  = DEVIATION FROM  $\lambda_a$  ( BRAGG  $\lambda$  )

F I G. 10G



FIXED, OR ESTABLISHED PARAMETERS:  $n_0$ ,  $\Delta n_1$ ,  $\theta_i$ ,  $\delta$ ,  $\delta\lambda$ ,  $\lambda_a$ ,  $T$ .

$$n_0 := 1.4$$

$$n_g := 1.515$$

$$\text{deg} = \frac{\pi}{180}$$

$$\Delta n_1 := 0, .001, \dots 2$$

$$\theta_i := 43 \text{ deg}$$

$$\theta_d := 26.6 \text{ deg}$$

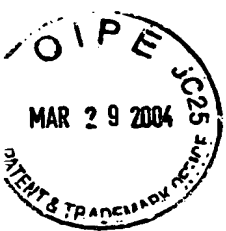
$$\delta := 0 \text{ deg}$$

$$\delta_\lambda := 0$$

$$T := 2.2$$

$$\lambda_a := .670$$

FIG. 10G1

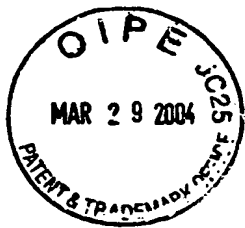


$$\left. \begin{aligned} (1) \alpha &:= \text{asin} \left[ \frac{\sin [\theta_i]}{n_0} \right] \\ (2) \beta &:= \text{asin} \left[ \frac{\sin [\theta_d]}{n_0} \right] \end{aligned} \right\} \begin{array}{l} \text{INTERNAL ANGLES DECIVED} \\ \text{FROM SNELL'S LAW AT} \\ \text{INTERFACIAL SURFACES} \end{array}$$

$$\left. \begin{aligned} (3) \phi &:= \frac{\pi}{2} - \frac{\beta - \alpha}{2} \\ (4) d &:= \frac{\lambda_a}{\sin [\theta_i] + \sin [\theta_d]} \\ (5) L &:= d \sin (\phi) \end{aligned} \right\} \begin{array}{l} \text{GRATING} \\ \text{EQUATION} \end{array}$$

$$\left. \begin{aligned} (6) C_R &:= \cos (\alpha) \\ (7) C_S &:= \cos (\alpha) - \frac{\lambda_a}{n_0 L} \cos (\phi) \\ (8) N[n_1] &:= \pi n_1 \frac{T}{\lambda_a \sqrt{C_R C_S}} \\ (9) \Gamma &:= 2 \pi \delta \frac{\sin (\phi - \alpha)}{L} - \delta_\lambda \frac{\pi}{n_0 L^2} \\ (10) S[n_1] &:= \Gamma \frac{T}{2 C_S} \end{aligned} \right\} \begin{array}{l} \text{FROM} \\ \text{"WAVE} \\ \text{COUPLING} \\ \text{THEORY"} \end{array}$$

FIG. 10H1



DIFFRACTION EFFICIENCIES:  $E_s$  AND  $E_p$  INCLUDING FRESNEL REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10% (ASSUMING  $n$  - glass = 1.515 AND ANGLES AS GIVEN BELOW)

$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 26.6 \text{ deg}$$

$$(11) \quad E_s[n_1] := \frac{\left[ \sin \left[ \sqrt{N[n_1]^2 + S[n_1]^2} \right] \right]^2}{1 + \frac{S[n_1]^2}{N[n_1]^2}} t_s(1 - .1)$$

$$(12) \quad E_p[n_1] := \frac{\left[ \sin \left[ \sqrt{[N[n_1] \cos(2(\alpha - \phi))]^2 + S[n_1]^2} \right] \right]^2}{1 + \frac{S[n_1]^2}{[N[n_1] \cos(2(\alpha - \phi))]^2}} t_p(1 - .1)$$

$$(13) \quad E_t[n_1] := E_s[n_1] \cdot [E_p[n_1]]$$

( $E_t$  IS THE TOTAL OUT-AND-BACK DIFFRACTION EFFICIENCY, ASSUMING THAT A CROSSED POLARIZER IS USED ON THE DETECTOR. IN THIS CASE, THE TOTAL EFFICIENCY IS JUST THE PRODUCT OF THE OUTGOING EFFICIENCY FOR THE INCIDENT P ( OR S ) POLARIZATION AND THE RETURN EFFICIENCY FOR THE ORTHOGONAL S ( OR P ) POLARIZATION. INCLUDES FRESNEL - REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10% )

$$(14) \quad H_1(\Delta n) := \frac{E_{t1}(\Delta n)}{E_{t16}(\Delta n)}$$

FIG. 10H2



**PARAMETERS FOR CALCULATING THE FRESNEL REFLECTION LOSSES AND TRANSMISSION**

$$\theta_{r,1} := \text{asin} \left[ \frac{\sin [\theta_i]}{n_g} \right]$$

$$\theta_{r,2} := \text{asin} \left[ \frac{\sin [\theta_d]}{n_g} \right]$$

$$R_{s,1} := \left[ \frac{\sin [\theta_i - \theta_{r,1}]}{\sin [\theta_i + \theta_{r,1}]} \right]^2$$

**S-POLARIZATION  
REFLECTION  
AT FIRST (ENTRY )  
SURFACE OF DISC**

$$R_{s,2} := \left[ \frac{\sin [\theta_d - \theta_{r,2}]}{\sin [\theta_d + \theta_{r,2}]} \right]^2$$

**S-POLARIZATION  
REFLECTION  
AT SECOND (EXIT )  
SURFACE OF DISC**

$$R_{p,1} := \left[ \frac{\tan [\theta_i - \theta_{r,1}]}{\tan [\theta_i + \theta_{r,1}]} \right]^2$$

**P-POLARIZATION  
REFLECTION  
AT FIRST (ENTRY )  
SURFACE OF DISC**

$$R_{p,2} := \left[ \frac{\tan [\theta_d - \theta_{r,2}]}{\tan [\theta_d + \theta_{r,2}]} \right]^2$$

**P-POLARIZATION  
REFLECTION  
AT SECOND (EXIT )  
SURFACE OF DISC**

**BOTH SURFACES**

$$t_s := [1 - R_{s,1}] \cdot [1 - R_{s,2}]$$

**S-POLARIZED  
FRESNEL TRANSMISSION**

$$t_p := [1 - R_{p,1}] \cdot [1 - R_{p,2}]$$

**P-POLARIZED  
FRESNEL TRANSMISSION**

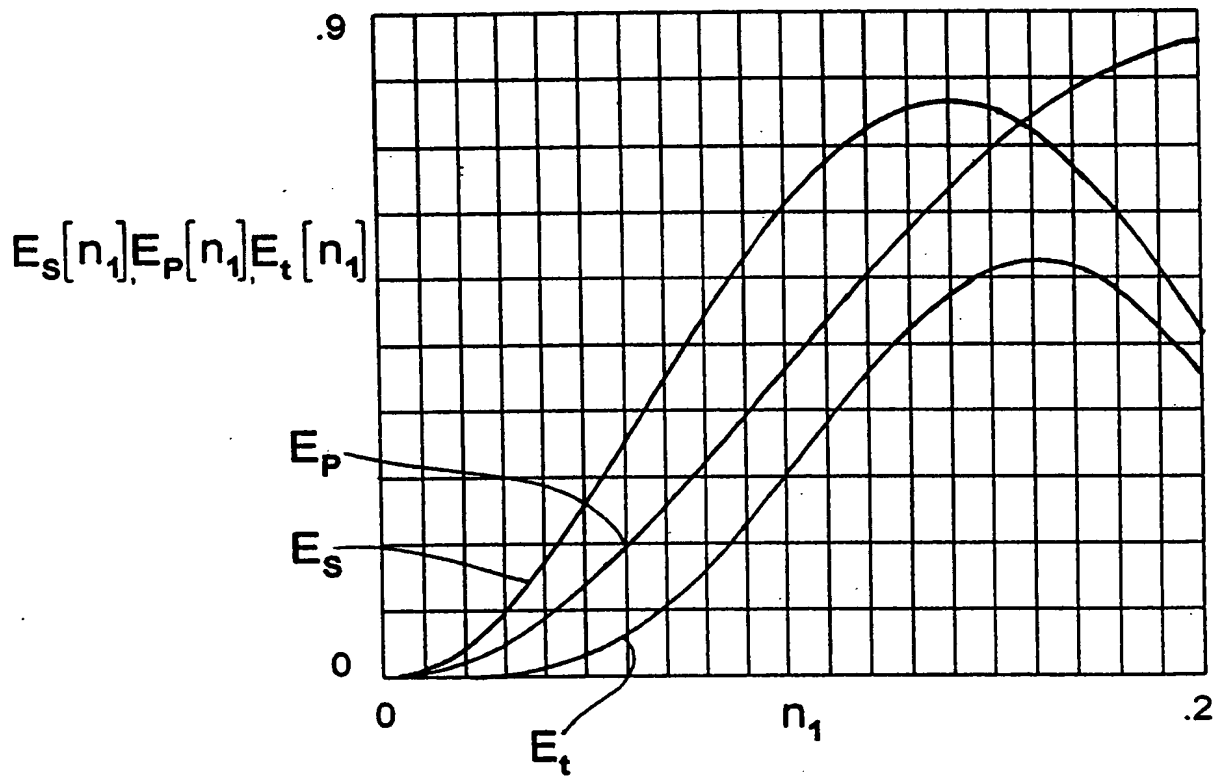
**FIG. 10H3**



DIFFRACTION EFFICIENCIES:  $E_s$ ,  $E_p$ ,  $E_t$  - INCLUDING FRESNEL  
REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10%.  
(ASSUMING  $n$  GLASS = 1.515 AND ANGLES ARE AS GIVEN BELOW )

$$\theta_i = 43 \text{ deg} \quad n_0 = 1.4 \quad \theta_d = 26.6 \text{ deg}$$

$$T = 2.2 \text{ microns} \quad \lambda_a = 0.67$$



FOR:  $n_1 := .16$

$$E_s[n_1] = 0.72915 \quad E_p[n_1] = 0.76037 \quad E_t[n_1] = 0.55442$$

$$H_1 := \frac{0.42745}{E_t[n_1]}$$

$$H_1 := 0.77098$$

H.1 IS THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 1 RELATIVE  
TO THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 16

FIG. 10I1



FACET No. 16

DIFFRACTION EFFICIENCIES:  $E_s$ ,  $E_p$ ,  $E_t$  - INCLUDING FRESNEL REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 10%.  
(ASSUMING  $n$  GLASS = 1.515 AND ANGLES ARE AS GIVEN BELOW)

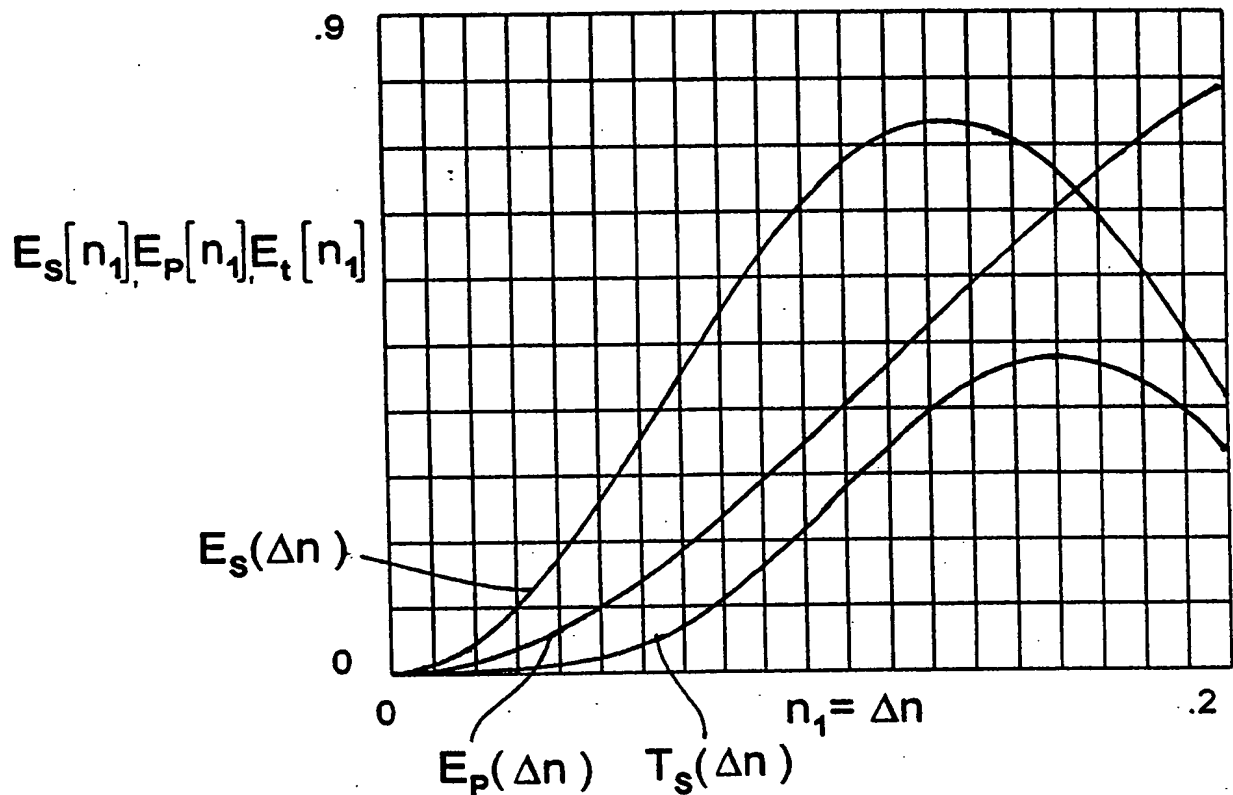
$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 41.8 \text{ deg}$$

$$n_0 = 1.4$$

$$T = 2.2 \text{ microns}$$

$$\lambda_a = 0.67$$



FOR:  $n_1 := .161$

$$E_s[n_1] = 0.67386$$

$$E_p[n_1] = 0.63433$$

$$E_t[n_1] = 0.42745$$

$$H_{16} := \frac{E_t[n_1]}{0.42745}$$

$$H_{16} = 1$$

H.16 IS THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 16  
RELATIVE TO THE OUT-AND-BACK DIFFRACTION EFFICIENCY OF FACET 16

FIG. 1012



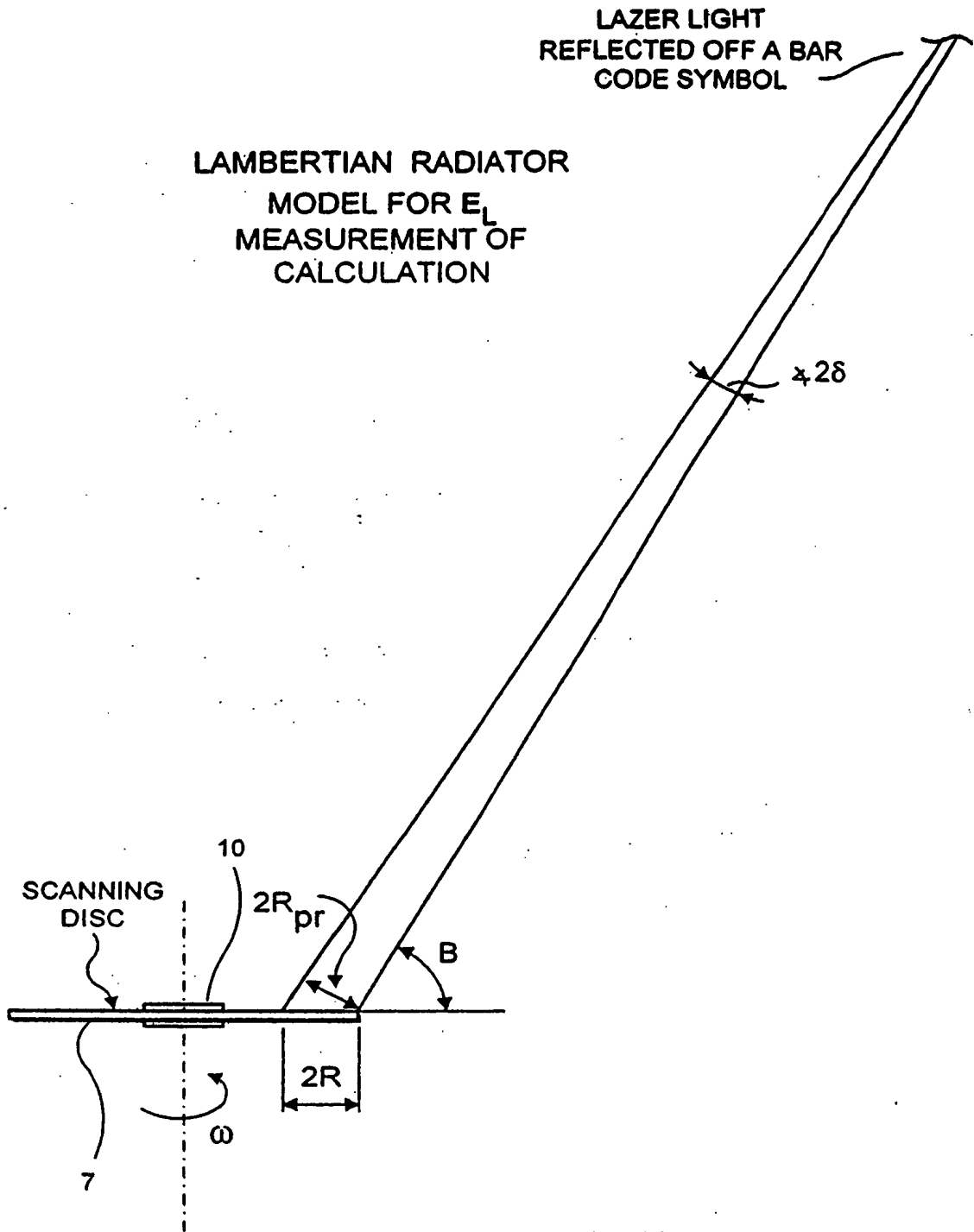


FIG. 10J



### FACET LIGHT COLLECTION EFFICIENCY

**Z** = DISTANCE FROM SCAN POINT ON LABEL ( MAX = FOCAL LENGTH PLUS 5 INCHES )

**A** = AREA OF CORRESPONDING FACET

**R** = RADIUS OF EFFECTIVE CIRCULAR APERTURE

**R.pr** = RADIUS OF PROJECTED EFFECTIVE CIRCULAR APERTURE

**B** = ANGLE BETWEEN OUTGOING BEAM AND THE DISC SURFACE

**$\delta$**  = HALF-ANGLE SUBTENDED BY EFFECTIVE PROJECTED CIRCULAR APERTURE

**E.L** = LAMBERTIAN LIGHT COLLECTION EFFICIENCY

FIG. 10K

$$R_{pr} := \sqrt{\frac{A \sin B}{\pi}} \quad \delta := \operatorname{atan} \left[ \frac{R_{pr}}{Z} \right]$$

$$E_L := (\sin(\delta))^2$$

FIG. 10L1

FOR FACET 16:

$$Z := 70 \text{ inches}$$

$$A := 4.7 \text{ square inches}$$

$$B := 48.2 \text{ deg}$$

$$\text{deg} = \frac{\pi}{180}$$

$$E_L := 0.00022756$$

FIG. 10L

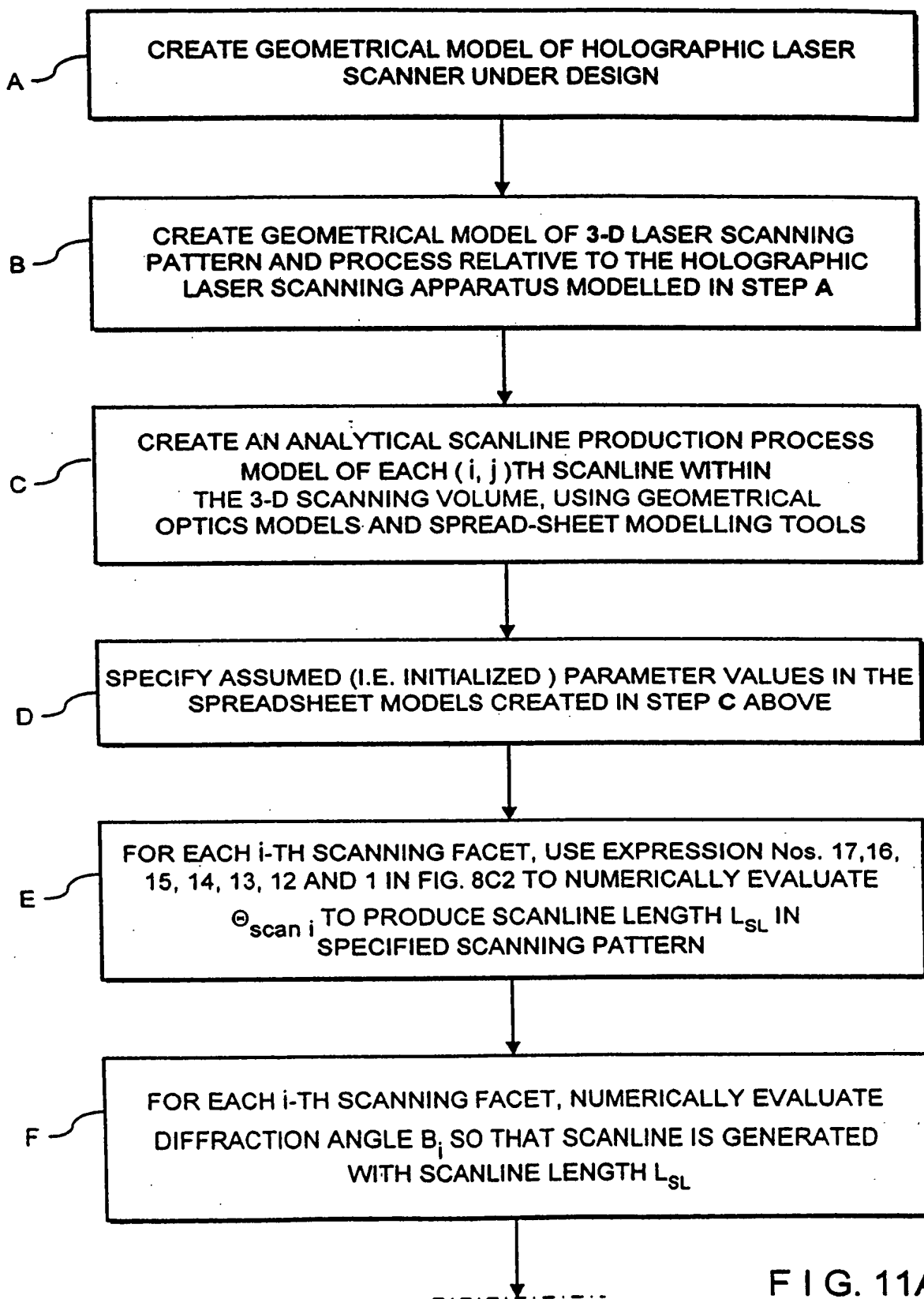


FIG. 11A

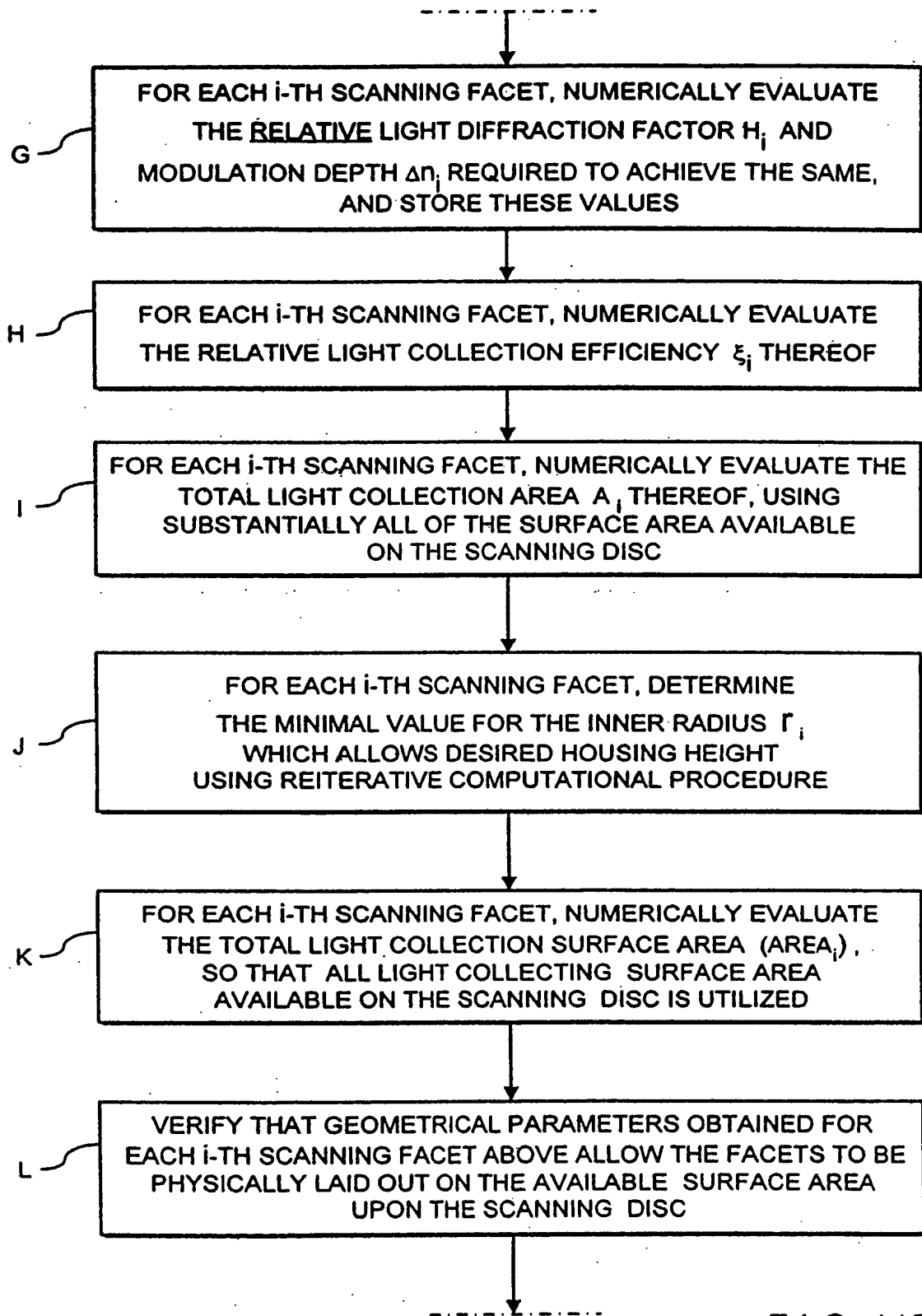
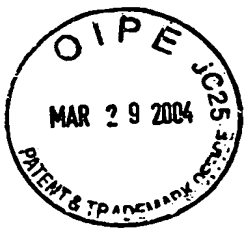
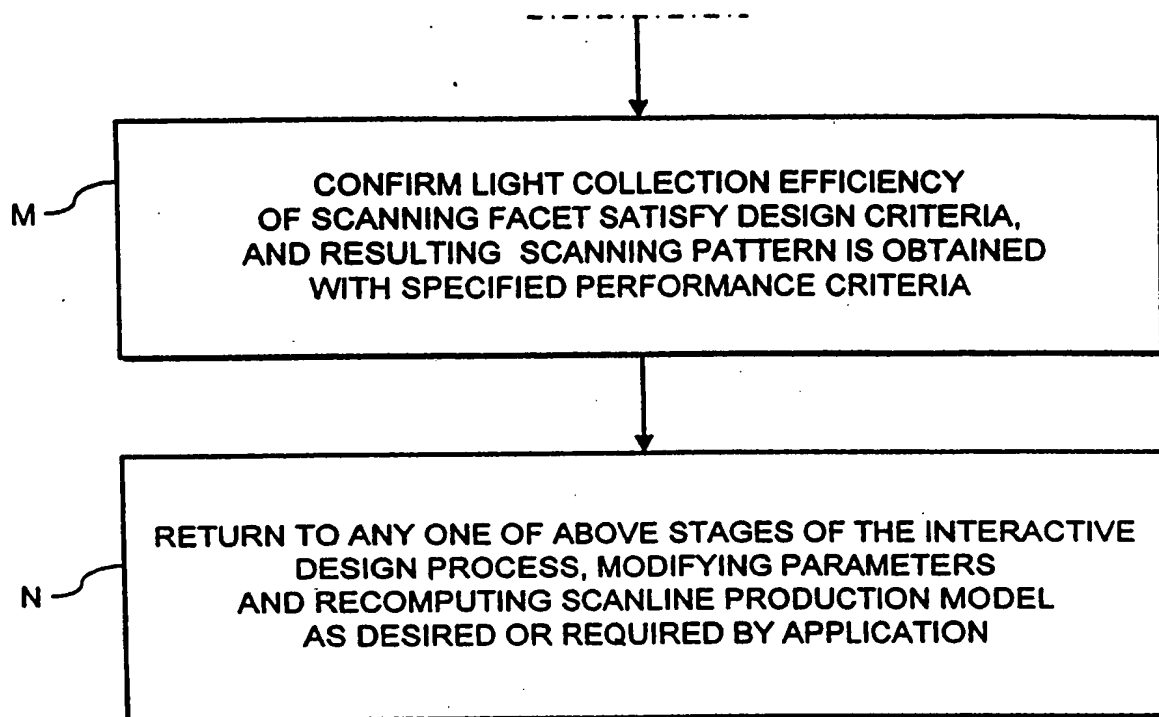
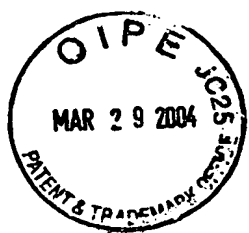


FIG. 11B



**FIG. 11C**



DIFFRACTION EFFICIENCIES:  $E_s$  AND  $E_p$  INCLUDING FRESNEL  
REFLECTION LOSSES AND ESTIMATED INTERNAL LOSSES OF 8%  
(ASSUMING  $n$  - glass = 1.515 AND ANGLES AS GIVEN BELOW)

$$\theta_i = 43 \text{ deg}$$

$$\theta_d = 47.5 \text{ deg}$$

$$n_0 = 1.4$$

$$T = 2.2 \text{ microns}$$

$$\lambda_a = 0.67$$

$$E_s[n_1] E_p[n_1]$$

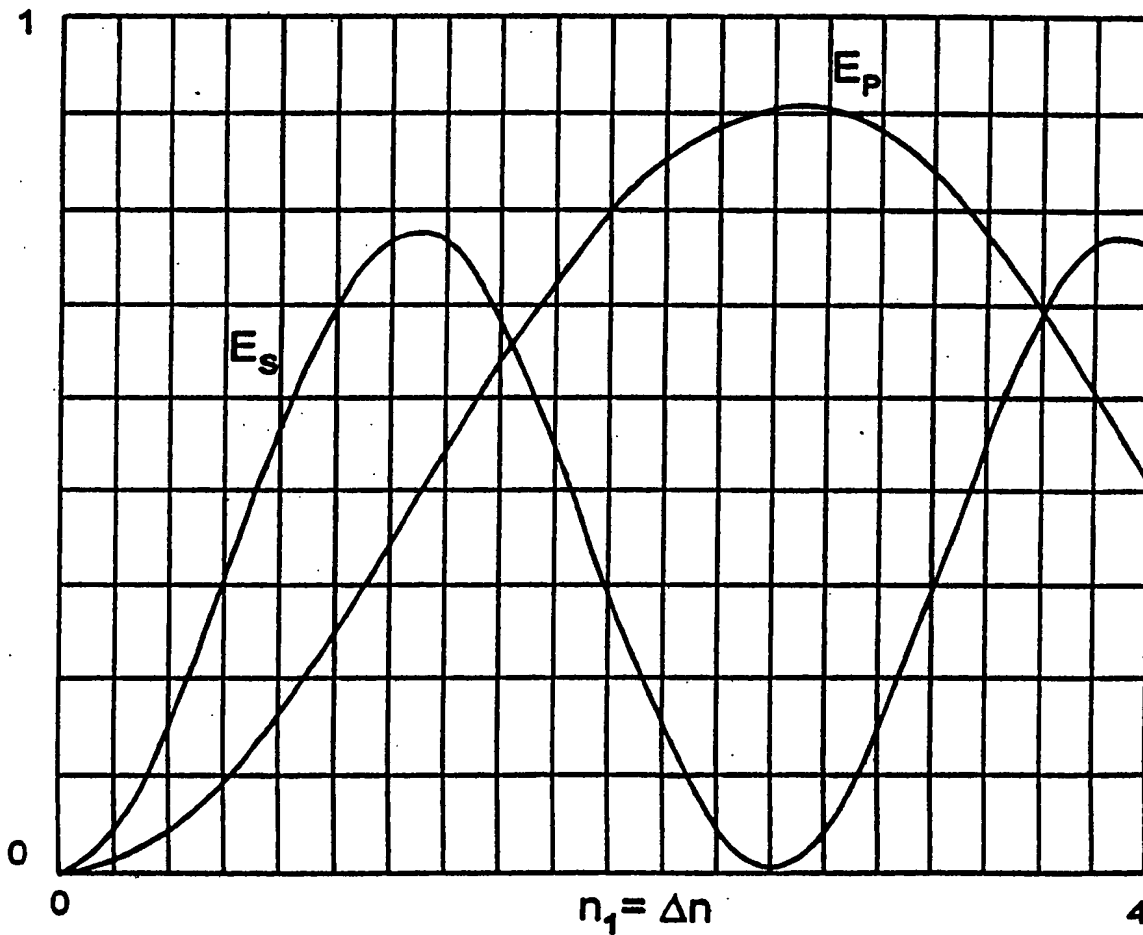


FIG. 12

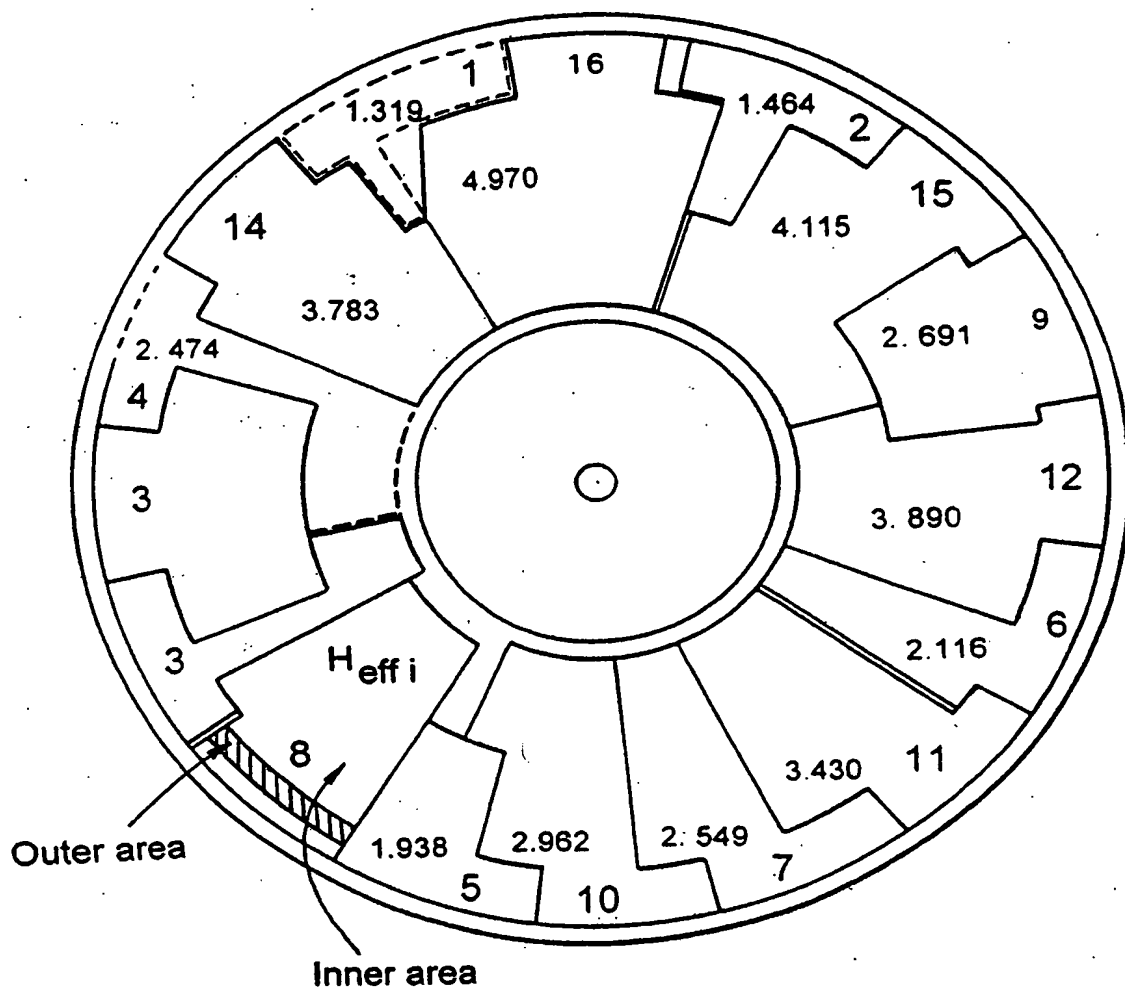


FIG. 12A

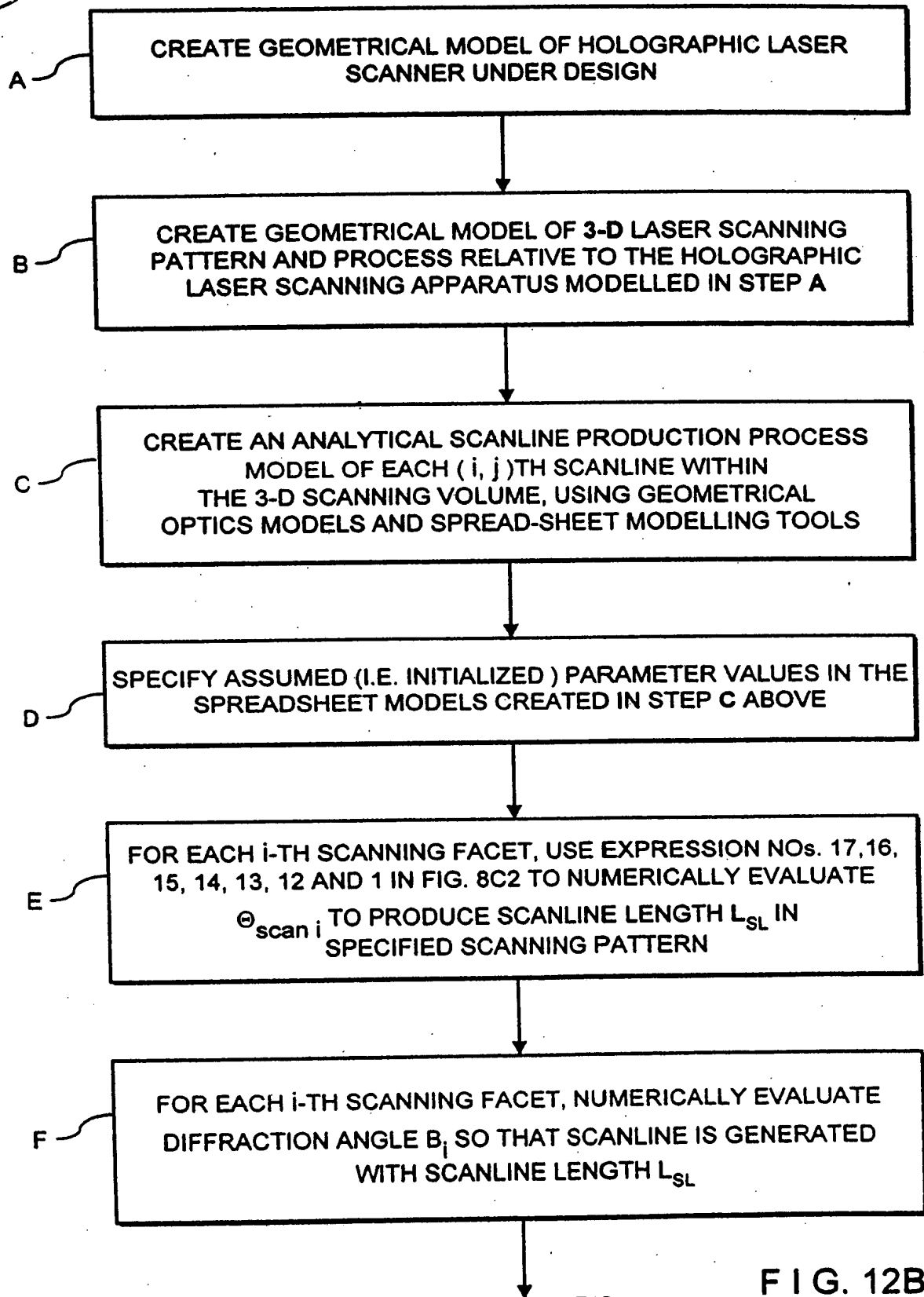


FIG. 12B1



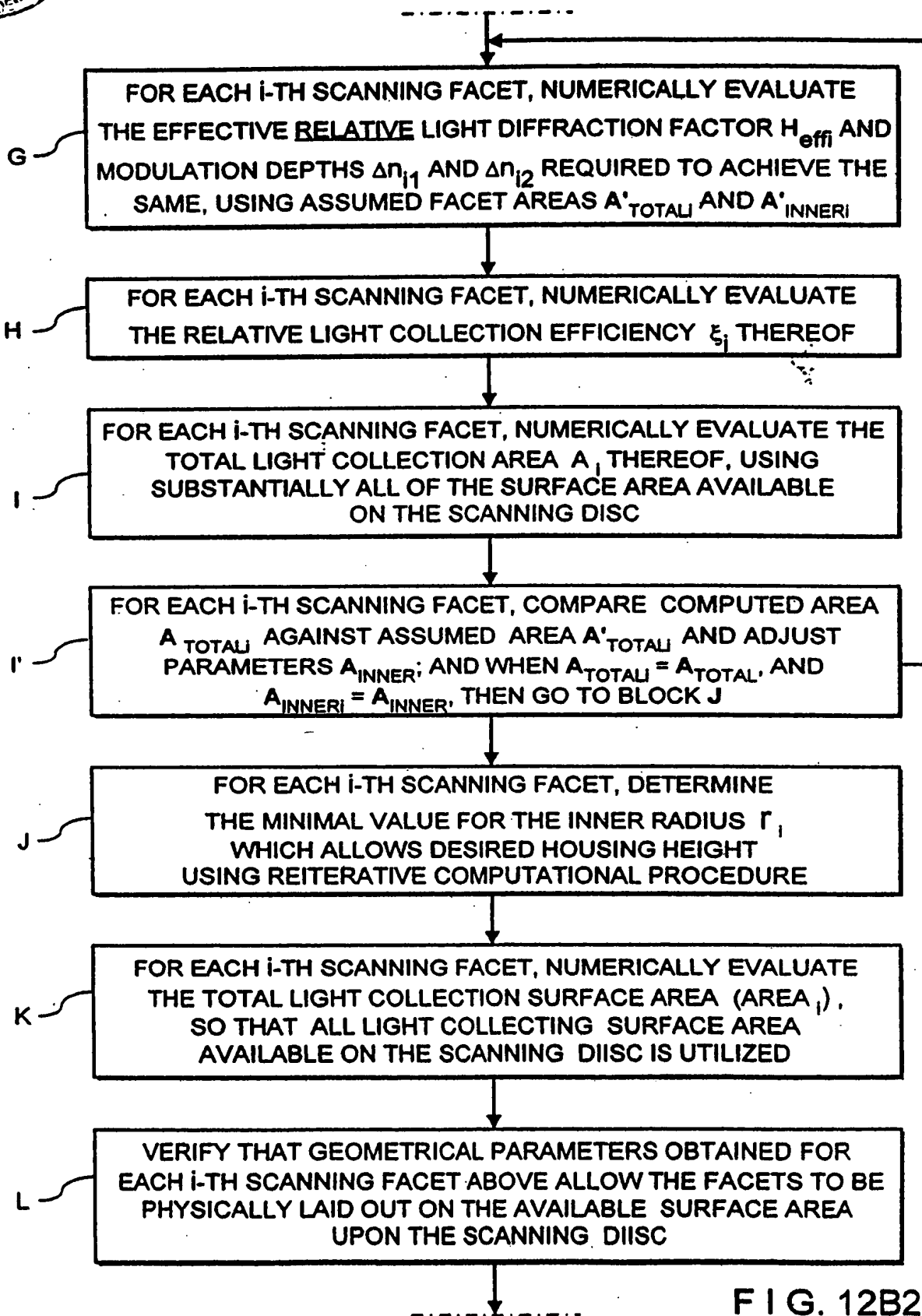


FIG. 12B2

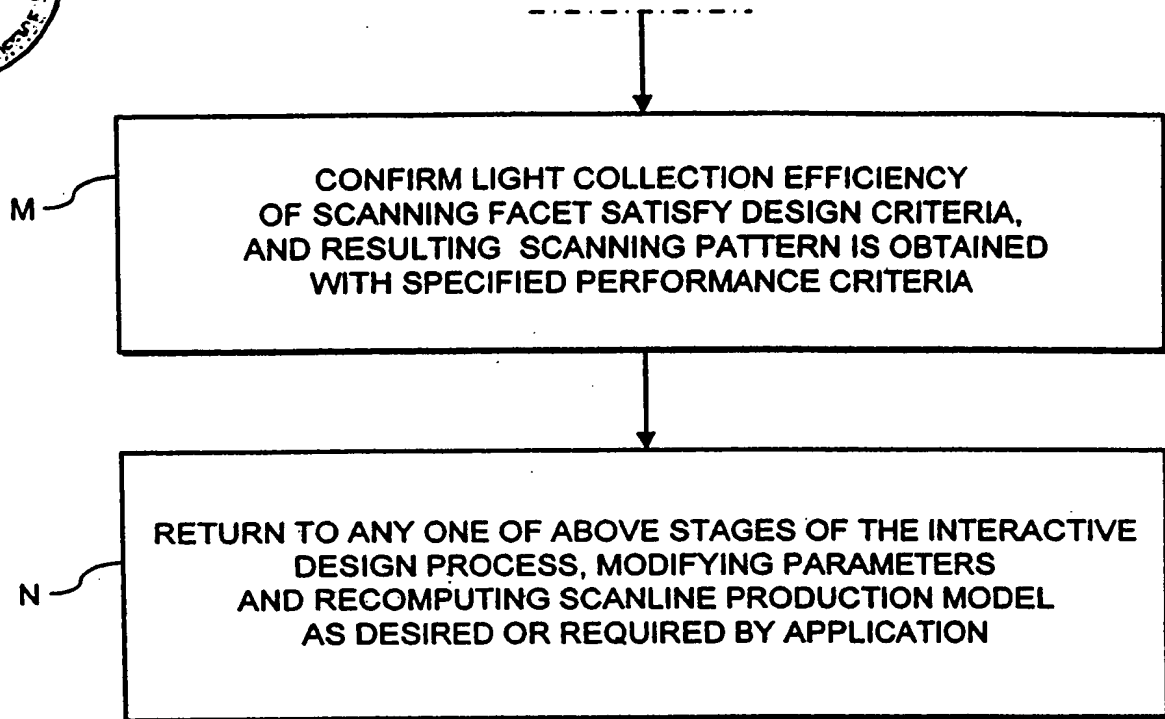


FIG. 12B3



$$H_1 := \frac{\frac{E_{S.o.16}}{A_{T.16}} \left[ E_{P.o.16} A_{o.16} + E_{P.i.16} A_{i.16} \right]}{\frac{E_{S.o.1}}{A_{T.1}} \left[ E_{P.o.1} A_{o.1} + E_{P.i.1} A_{i.1} \right]}$$

WHERE :

**E.S.o.16** = S-POLARIZATION EFFICIENCY OF THE OUTER SEGMENT OF FACET 16

**E.S.o.1** = S-POLARIZATION EFFICIENCY OF THE OUTER SEGMENT OF FACET 1

**E.P.o.16** = P-POLARIZATION EFFICIENCY OF THE OUTER SEGMENT OF FACET 16

**E.P.o.1** = P-POLARIZATION EFFICIENCY OF THE OUTER SEGMENT OF FACET 1

**E.P.i.16** = P-POLARIZATION EFFICIENCY OF THE INNER SEGMENT OF FACET 16

**E.P.i.1** = P-POLARIZATION EFFICIENCY OF THE INNER SEGMENT OF FACET 1

**A.T.16** = TOTAL AREA OF FACET 16

**A.T.1** = TOTAL AREA OF FACET 1

**A.o.16** = OUTER AREA OF FACET 16

**A.o.1** = OUTER AREA OF FACET 1

**A.i.16** = OUTER AREA OF FACET 16

**A.i.1** = OUTER AREA OF FACET 1

**FIG. 12C**

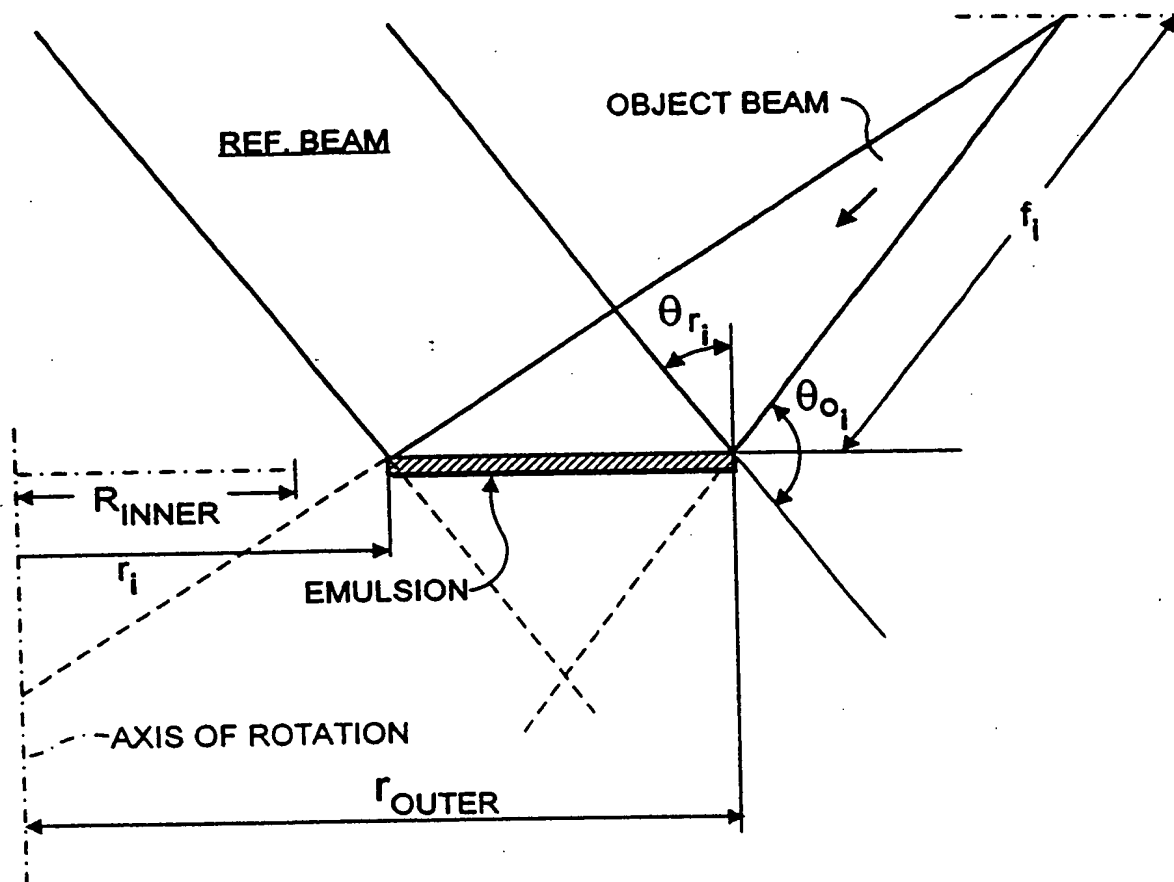


FIG. 13

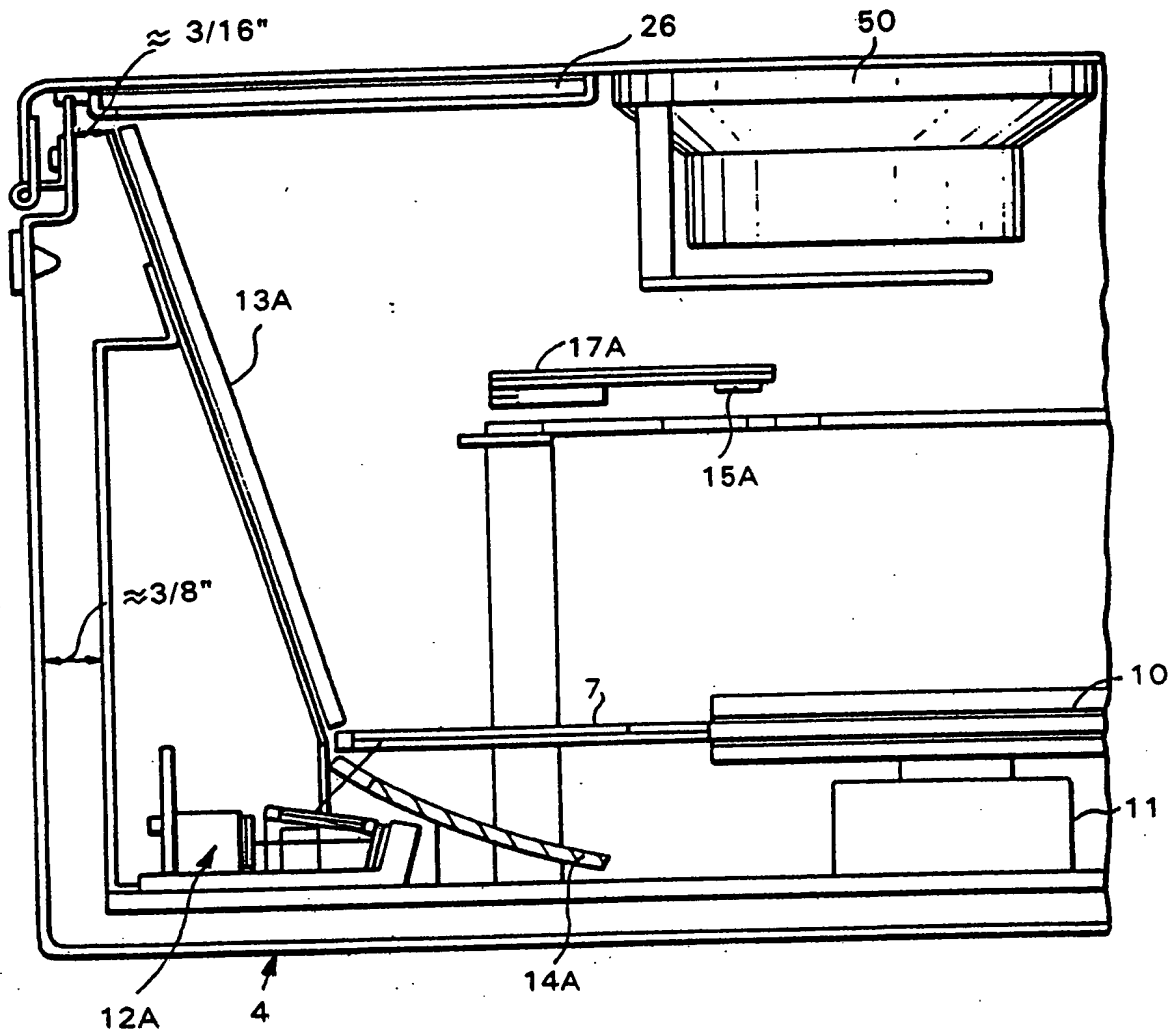
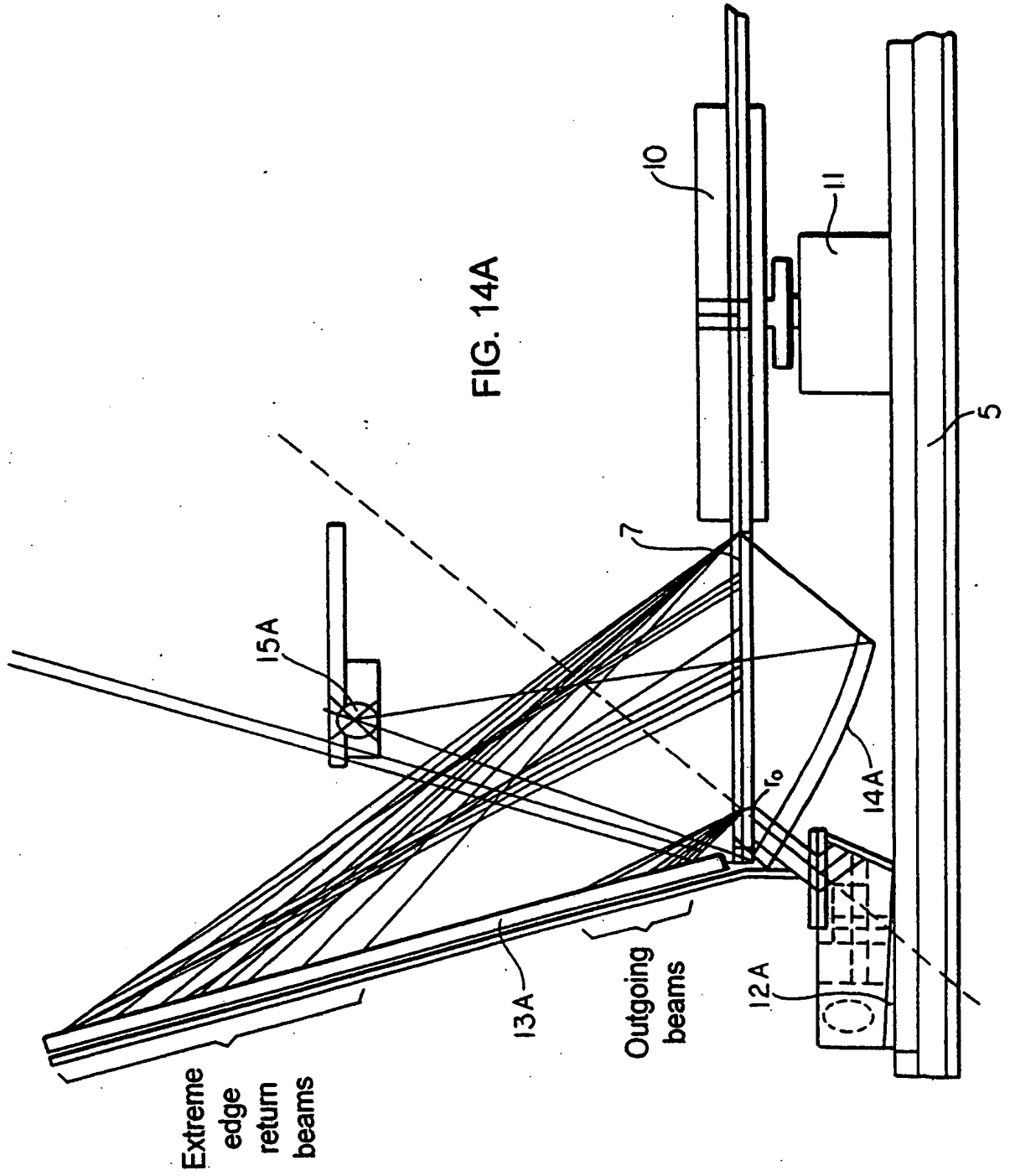


FIG. 14



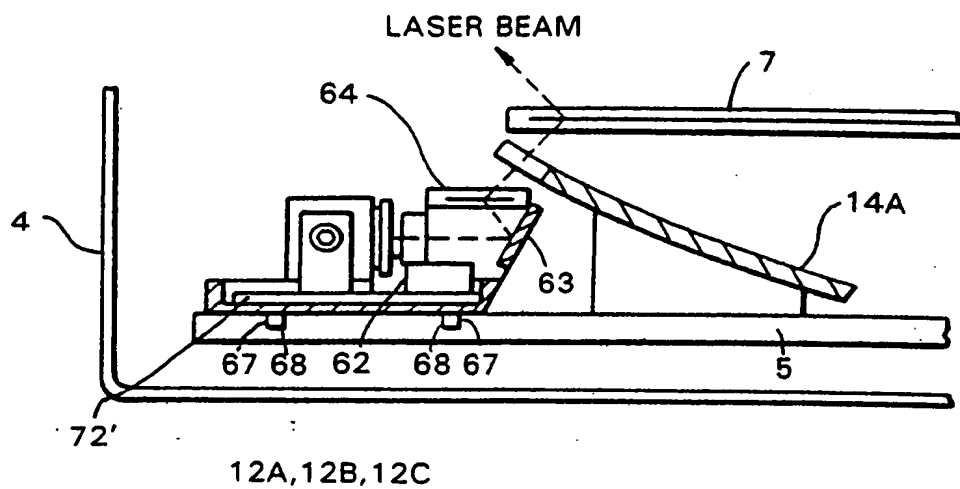


FIG. 15

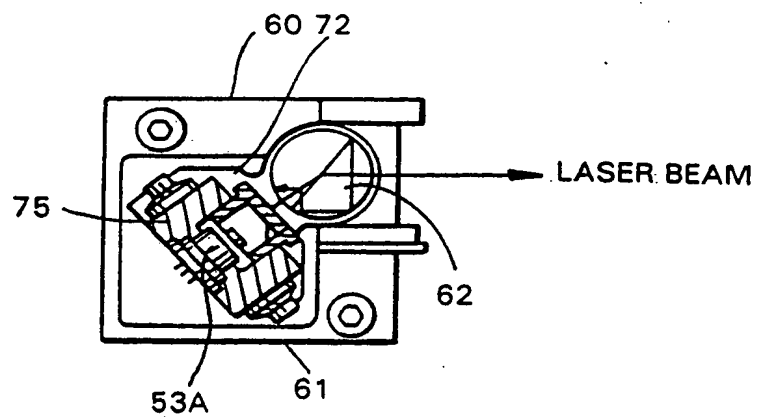


FIG. 15A

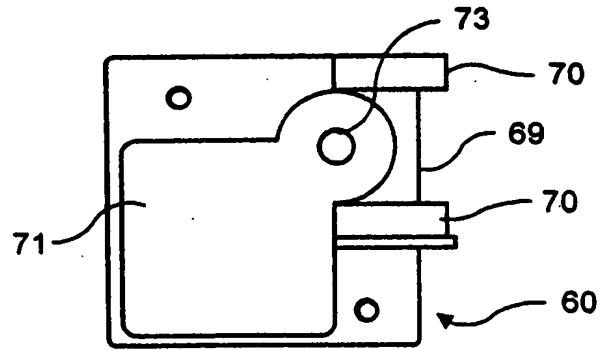


FIG. 15B

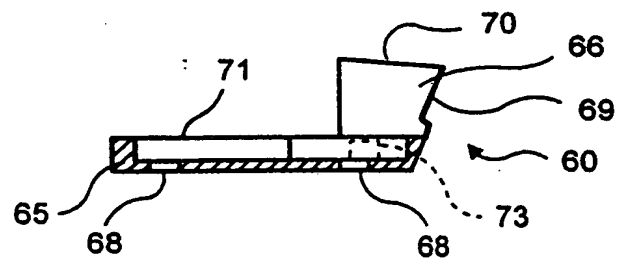


FIG. 15C

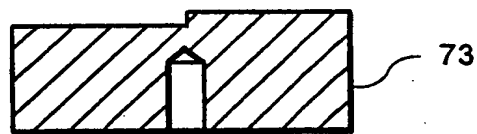


FIG. 15D1

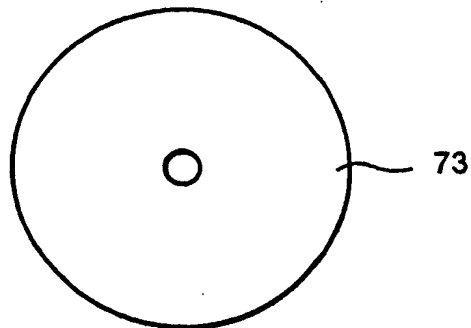


FIG. 15D2



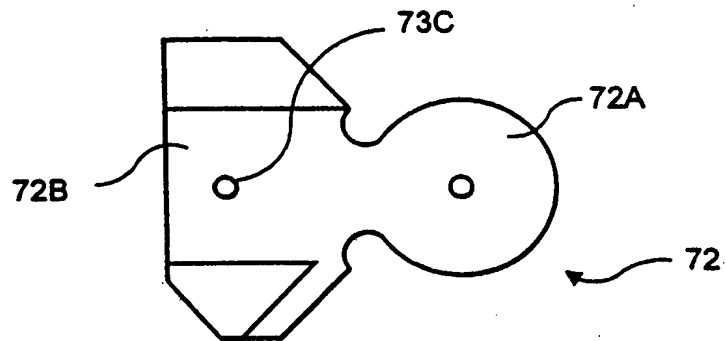


FIG. 15E1

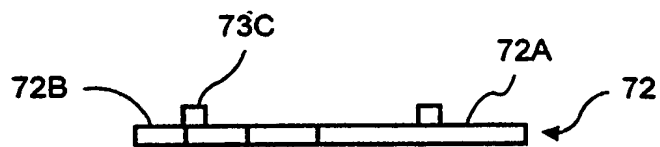


FIG. 15E2

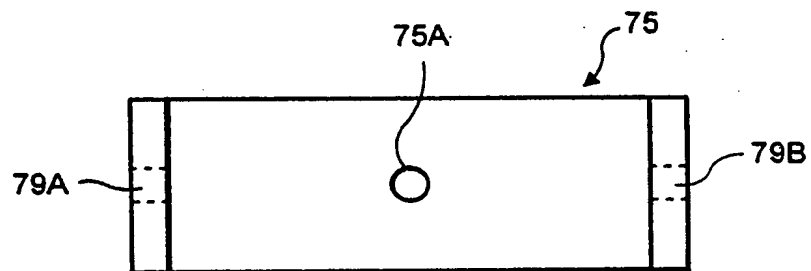


FIG. 15F1

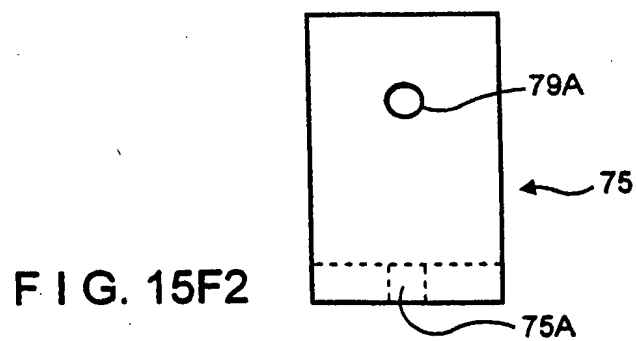


FIG. 15F2

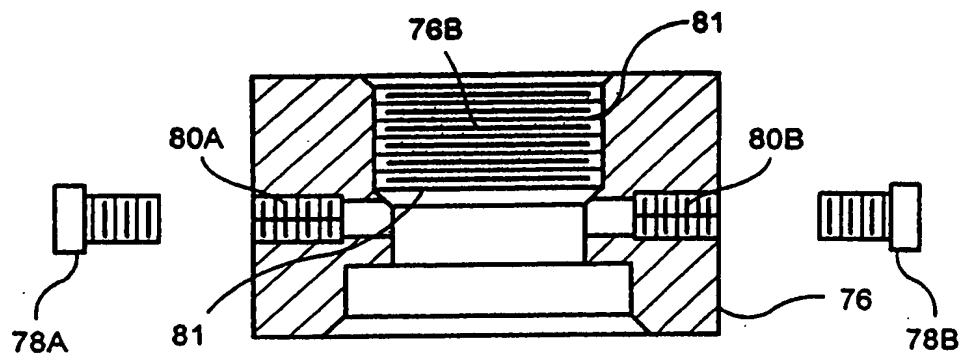


FIG. 15G1

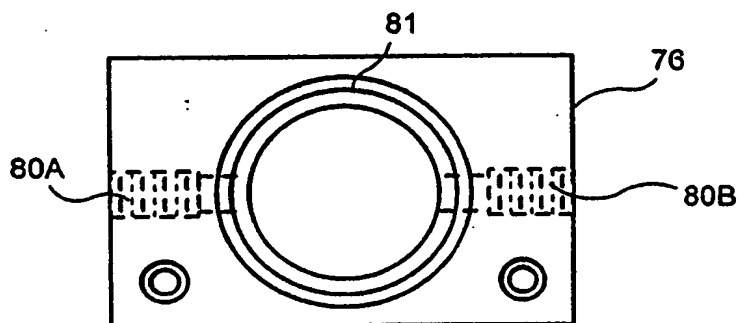


FIG. 15G2

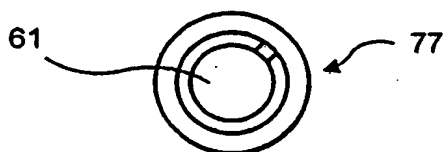


FIG. 15H1

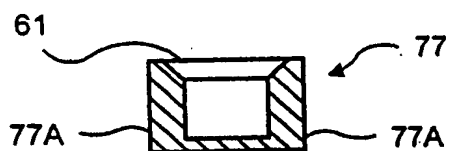


FIG. 15H2

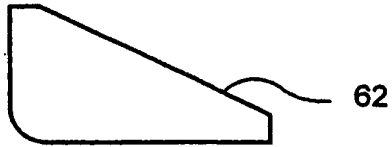


FIG. 15I1

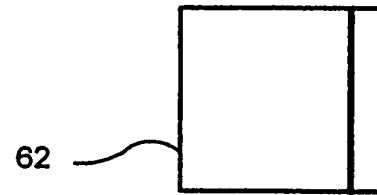


FIG. 15I2

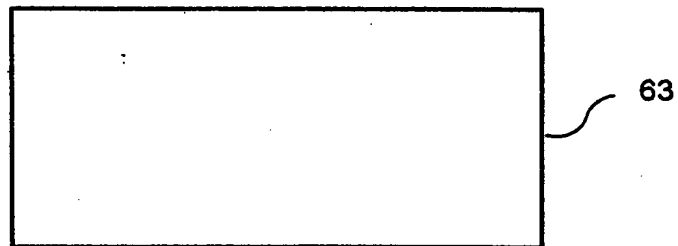


FIG. 15J

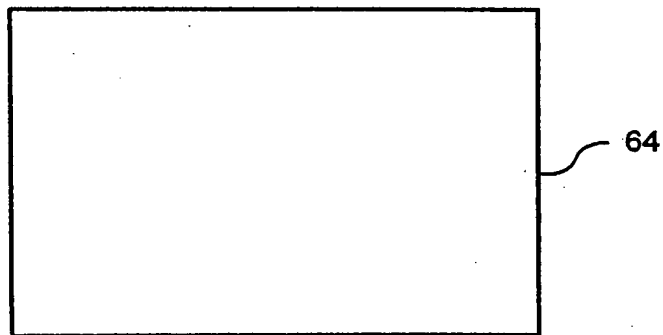


FIG. 15K

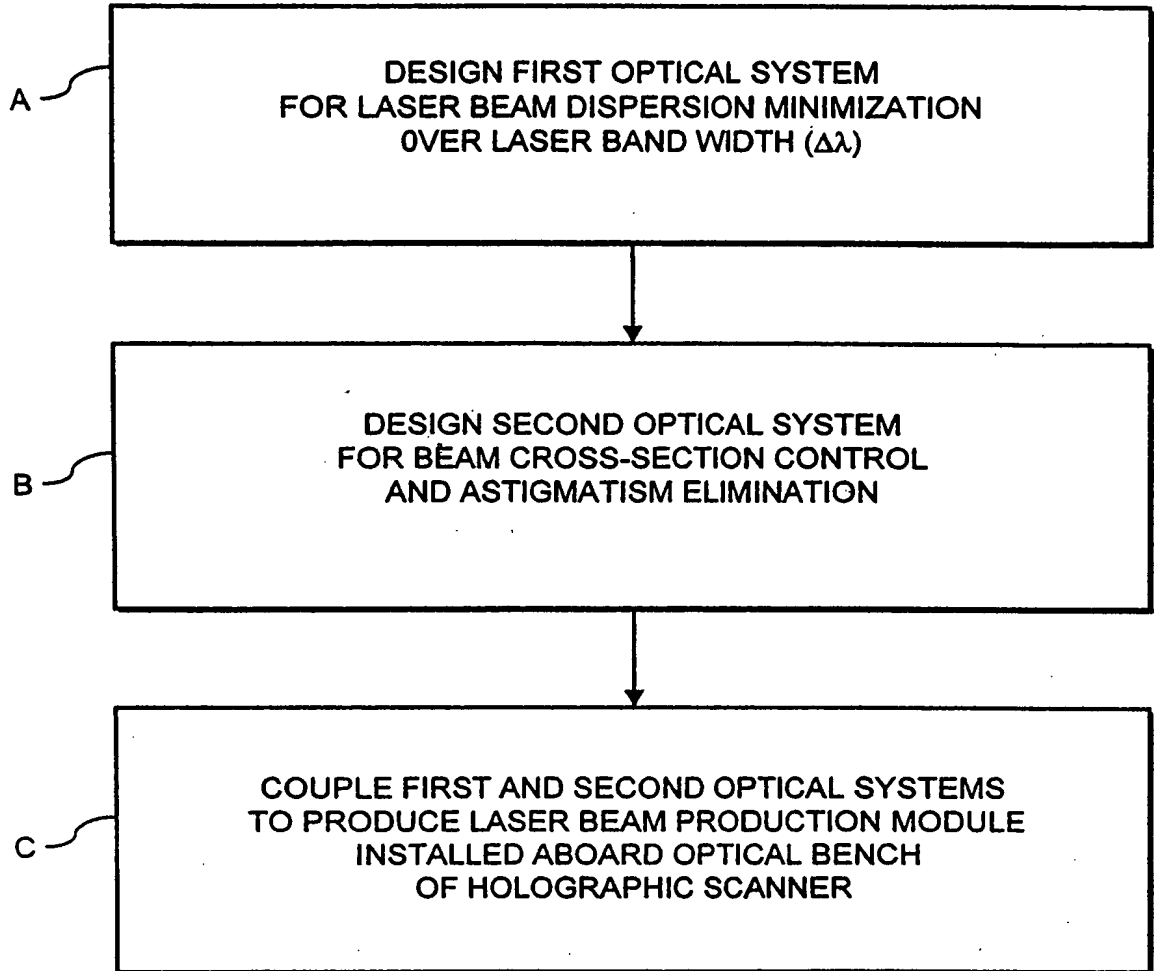
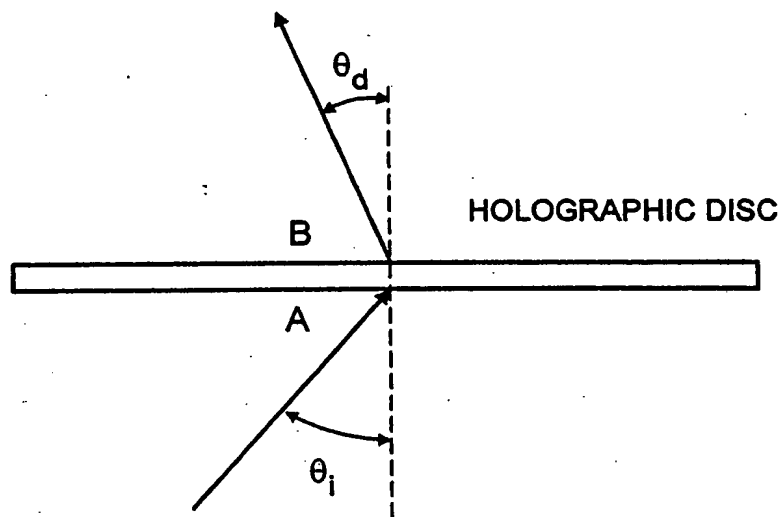


FIG. 16



$\theta_i$  = ANGLE OF INCIDENCE

$\theta_d$  = ANGLE OF DIFFRACTION

A = 90 DEGREES MINUS ANGLE  $\theta_i$

B = 90 DEGREES MINUS ANGLE  $\theta_d$

FIG. 17A



$\theta_{i.2}$  = ANGLE OF INCIDENCE AT HOLOGRAPHIC FACET

$\theta_{d.c.2}$  = CONSTRUCTION ANGLE OF DIFFRACTION FOR HOLOGRAPHIC FACET

$\theta_{d.2}$  = ANGLE OF DIFFRACTION OF HOLOGRAPHIC FACET

$\lambda$  = WAVELENGTH (IN AIR)

$\lambda_c$  = CONSTRUCTION WAVELENGTH FOR HOLOGRAPHIC FACET

$d_2$  = GRATING SPACING IN HOLOGRAPHIC FACET

FIG. 17B

$$\text{deg} := \frac{\pi}{180}$$

$$\lambda_c := .670 \text{ microns}$$

$$\lambda := .650, .651, \dots, .690 \text{ microns}$$

$$\theta_{i.2} := 43 \text{ deg}$$

$$\theta_{d.c.2} := 37 \text{ deg}$$

FIG. 17B1

$$d_2 := \frac{\lambda_c}{\sin[\theta_{i.2}] + \sin[\theta_{d.c.2}]} \text{ microns} \quad d_2 = 0.52188$$

$$\theta_{d.2}(\lambda) := \text{asin} \left[ \left[ \frac{\lambda}{d_2} \right] - \sin[\theta_{i.2}] \right]$$

FIG. 17C

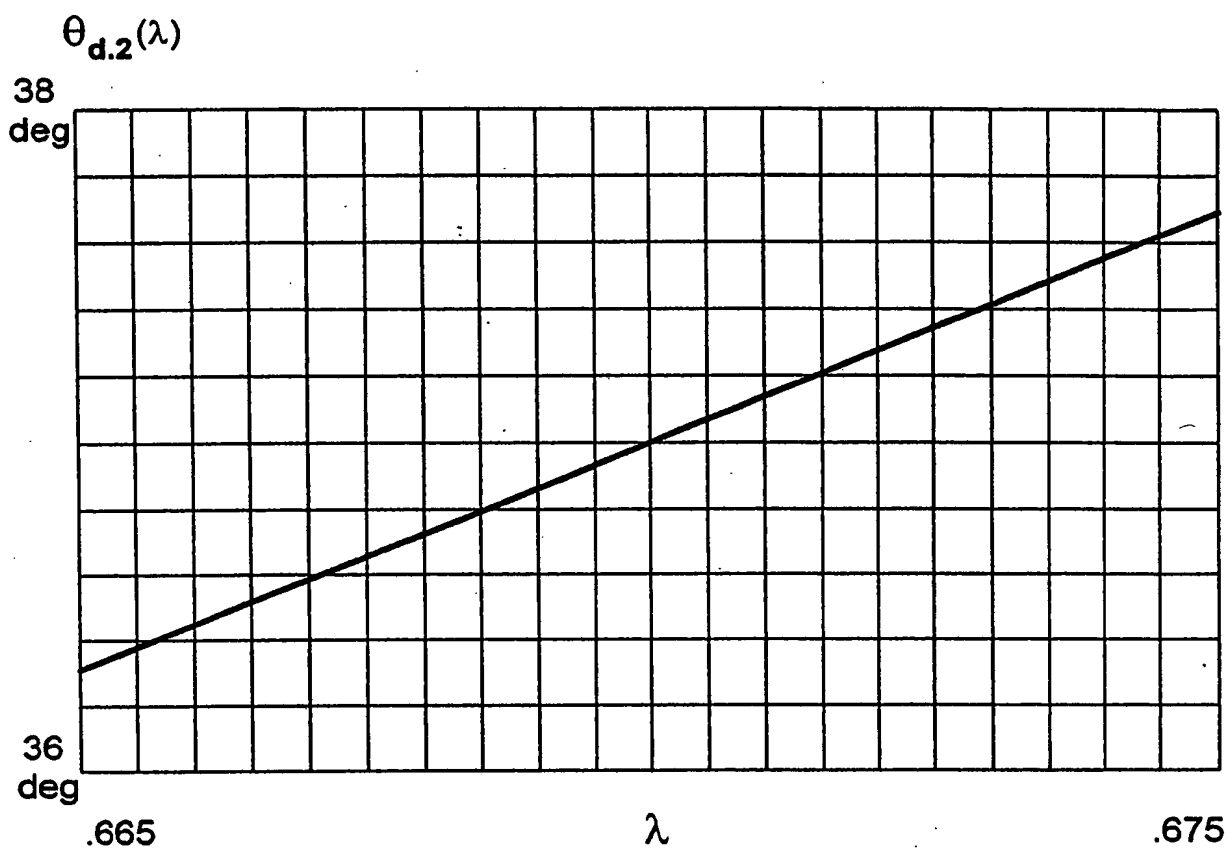


FIG. 17D

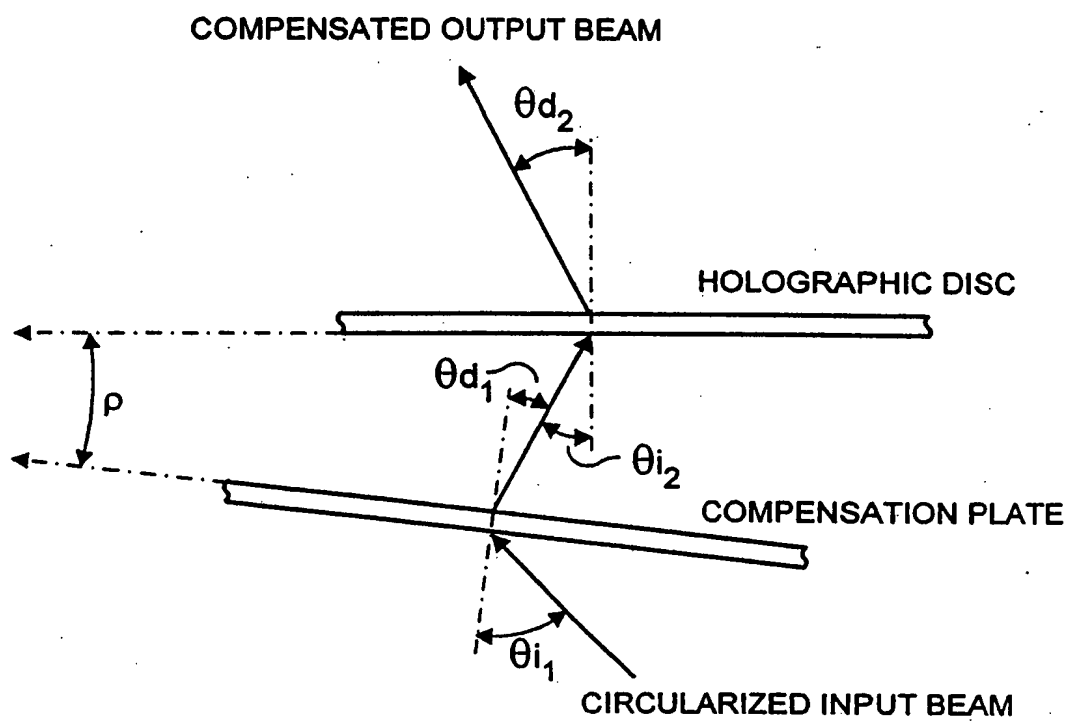


FIG. 18A





COMPENSATION PLATE ADDED - WITH TILT ANGLE.  
TILT ANGLE RELATIVE TO HOLOGRAPHIC FACET -  $\rho$

$\theta_{i.1}$  = ANGLE OF INCIDENCE FOR COMPENSATION PLATE ( FIXED )

$\theta_{d.c.1}$  = CONSTRUCTION ANGLE OF DIFFRACTION OF COMPENSATION  
PLATE

$\theta_{d.1}$  = ANGLE OF DIFFRACTION OF COMPENSATION PLATE

$\lambda$  = WAVELENGTH ( IN AIR )

$\lambda.c$  = CONSTRUCTION WAVELENGTH

$d.1$  = GRATING SPACING IN COMPENSATION PLATE

$\rho$  = TILT ANGLE OF COMPENSATION PLATE RELATIVE TO  
HOLOGRAPHIC FACET

FIG. 18B

$$\theta_{i.1} := 41.5 \text{ deg}$$

$$\rho := -1.5 \text{ deg}$$

$$d_1 = 0.50557 \text{ deg}$$

$$\theta_{d.c.1} = 41.5 \text{ deg}$$

$$\theta_{d.c.2} := 37 \text{ deg}$$

FIG. 18B1



$$\theta_{d.c.1} = \theta_{i.2} + \rho$$

$$(1) \quad d_1 := \frac{\lambda_c}{\sin [\theta_{i.1}] + \sin [\theta_{d.c.1}]} \text{ microns}$$

$$(2) \quad \theta_{d.1}(\lambda) := \text{asin} \left[ \left[ \frac{\lambda}{d_1} \right] - \sin [\theta_{i.1}] \right]$$

$$(3) \quad \theta_{d.2}(\lambda) :=$$

$$= \text{asin} \left[ \frac{\lambda}{d_2} - \sin \left[ \text{asin} \left[ \frac{\lambda}{d_1} - \sin [\theta_{i.1}] \right] - \rho \right] \right]$$

FIG. 18C

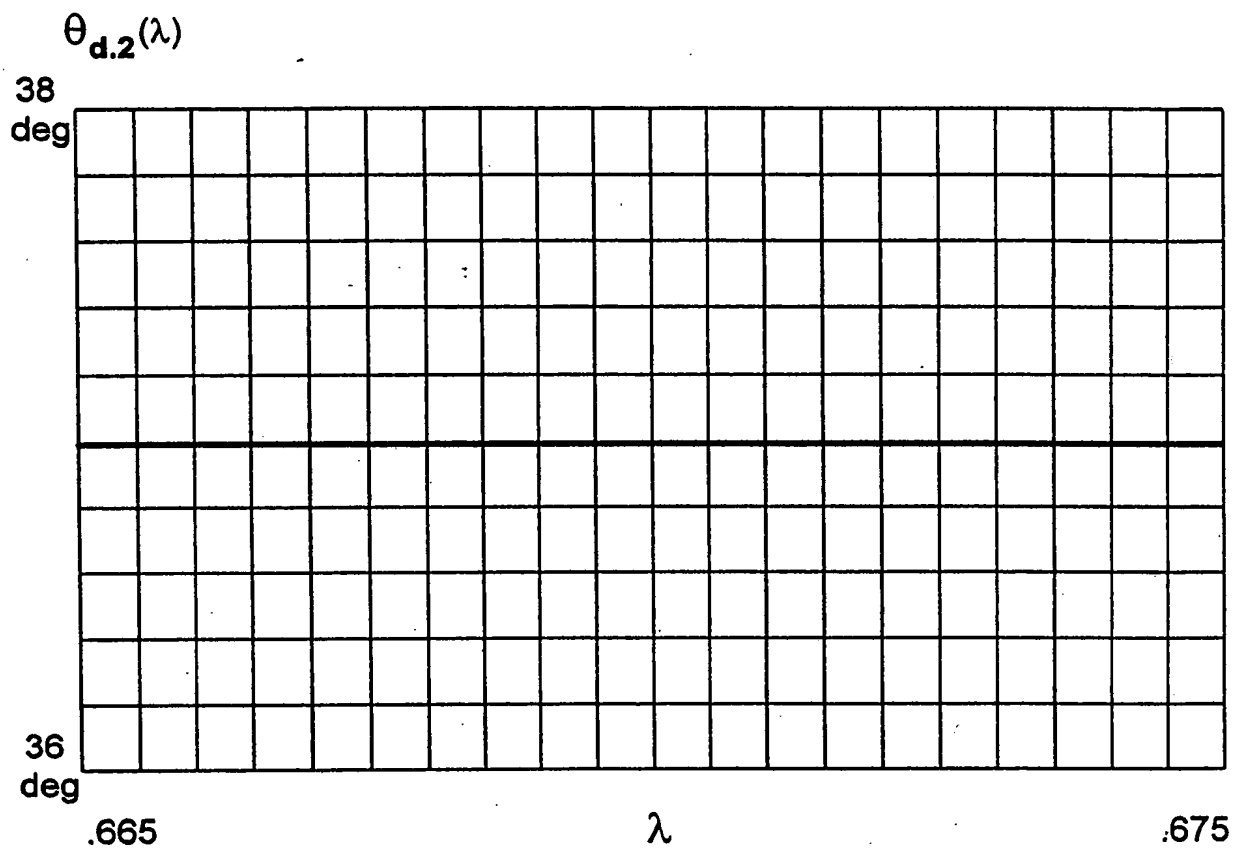
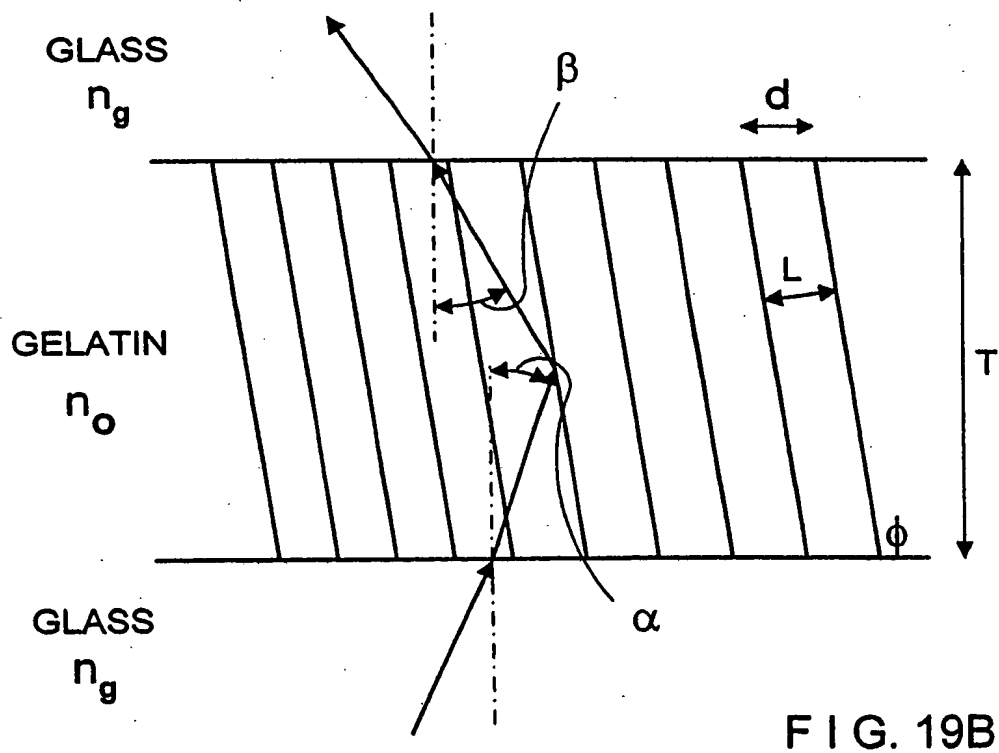
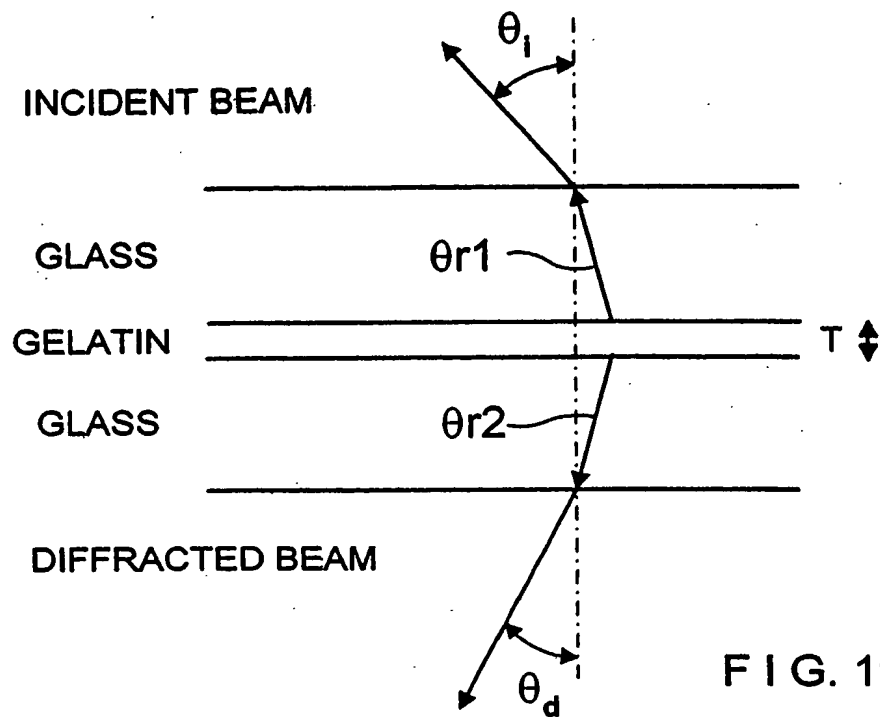


FIG. 18D





CHANGE IN CONSTRUCTION BEAM ANGLES FOR A CHANGE IN WAVELENGTH BETWEEN CONSTRUCTION AND RECONSTRUCTION. THIS PROGRAM CALCULATES THE EXTERNAL ANGLE OF INCIDENCE AND EXTERNAL ANGLE OF DIFFRACTION FOR THE CONSTRUCTION WAVELENGTH WHEN THE EXTERNAL ANGLE OF INCIDENCE AND EXTERNAL ANGLE OF DIFFRACTION ARE GIVEN FOR THE RECONSTRUCTION WAVELENGTH. BRAGG CONDITION IS MAINTAINED IN BOTH CASES SO THAT THE BRAGG PLANE TILT IS UNCHANGED.

$$\text{deg} = \frac{\pi}{180}$$

$n_0 := 1.53$	AVERAGE REFRACTIVE INDEX OF THE MEDIUM BEFORE PROCESSING
$n_2 := 1.4$	AVERAGE REFRACTIVE INDEX OF THE MEDIUM AFTER PROCESSING
$\lambda_1 := 0.670$	RECONSTRUCTION WAVELENGTH (VISIBLE LASER DIODE)
$\lambda_2 := 0.488$	CONSTRUCTION WAVELENGTH (ARGON LASER)
$\theta_{i,1} := 41.5 \text{ deg}$	ANGLE OF INCIDENCE AT RECONSTRUCTION
$\theta_{d,1} := 41.5 \text{ deg}$	ANGLE OF DIFFRACTION AT RECONSTRUCTION

FIG. 19C

HOE CONSTRUCTION ANGLES AT SECOND WAVELENGTH

REFERENCE BEAM

OBJECT BEAM

$$\theta_e = \theta_{i,2} = 28.857 \text{ deg}$$

$$\theta_o = \theta_{d,2} = 28.857 \text{ deg}$$

FIG. 19E



$$(1) \alpha_1 := \text{asin} \left[ \frac{\sin [\theta_{i.1}]}{n_2} \right]$$

ANGLE OF INCIDENCE INSIDE  
THE MEDIUM AFTER PROCESSING

$$\alpha_1 = 28.249 \text{ deg}$$

$$(2) \beta_1 := \text{asin} \left[ \frac{\sin [\theta_{d.1}]}{n_2} \right]$$

ANGLE OF DIFFRACTION INSIDE  
THE MEDIUM AFTER PROCESSING

$$\beta_1 = 28.249 \text{ deg}$$

$$d := \frac{\lambda_1}{\sin [\theta_{i.1}] + \sin [\theta_{d.1}]}$$

$$d = 0.506 \text{ microns}$$

$$\frac{1000}{d} = 1.978 \cdot 10^3 \text{ lines per mm.}$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta_1 - \alpha_1}{2}$$

TILT ANGLE OF THE BRAGG PLANES

$$\phi = 90 \text{ deg}$$

$$(4) \theta_{0.1} := \alpha_1 + \frac{\pi}{2} - \phi$$

ANGLE RELATIVE TO THE BRAGG  
PLANES

$$\theta_{0.1} = 28.249 \text{ deg}$$

$$(6) L := \frac{\lambda_1}{2 n_2 \sin [\theta_{0.1}]}$$

SEPARATION OF THE BRAGG  
PLANES.

BRAGG CONDITION EQUATION.

$$\frac{1}{L} = 1.978 \quad \frac{1}{L} \sin(\phi) = 1.978$$

$$(7) \theta_{0.2} := \text{asin} \left[ \frac{\lambda_2}{2 n_0 L} \right]$$

ANGLE RELATIVE TO THE BRAGG  
PLANES FOR THE SECOND  
WAVELENGTH SATISFYING THE  
BRAGG CONDITION - BEFORE  
PROCESSING

$$\theta_{0.2} = 18.387 \text{ deg}$$

FIG. 19D1



$$(8) \alpha_2 := \theta_{0.2} + \phi - \frac{\pi}{2}$$

ANGLE OF INCIDENCE INSIDE  
THE MEDIUM FOR THE SECOND  
WAVELENGTH - BEFORE PROCESSING

$$\alpha_2 = 18.387 \text{ deg}$$

$$(9) \beta_2 := \alpha_2 + \pi - 2\phi$$

ANGLE OF DIFFRACTION INSIDE  
THE MEDIUM FOR THE SECOND  
WAVELENGTH - BEFORE PROCESSING

$$\beta_2 = 18.387 \text{ deg}$$

$$(10) \theta_{i.2} := \text{asin} [n_0 \sin [ \alpha_2 ]]$$

ANGLE OF INCIDENCE  
( REFERENCE BEAM ) FOR THE  
SECOND WAVELENGTH -  
EXTERNAL

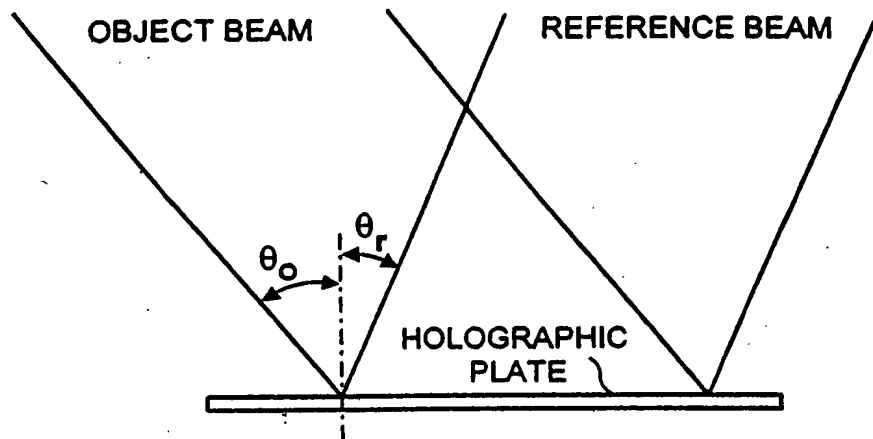
$$\theta_{i.2} = 28.857 \text{ deg}$$

$$(11) \theta_{d.2} := \text{asin} [n_0 \sin [ \beta_2 ]]$$

ANGLE OF DIFFRACTION  
( OBJECT BEAM ) FOR THE  
SECOND WAVELENGTH -  
EXTERNAL

$$\theta_{d.2} = 28.857 \text{ deg}$$

FIG. 19D2



$\theta_o$  = OBJECT BEAM ANGLE OF INCIDENCE

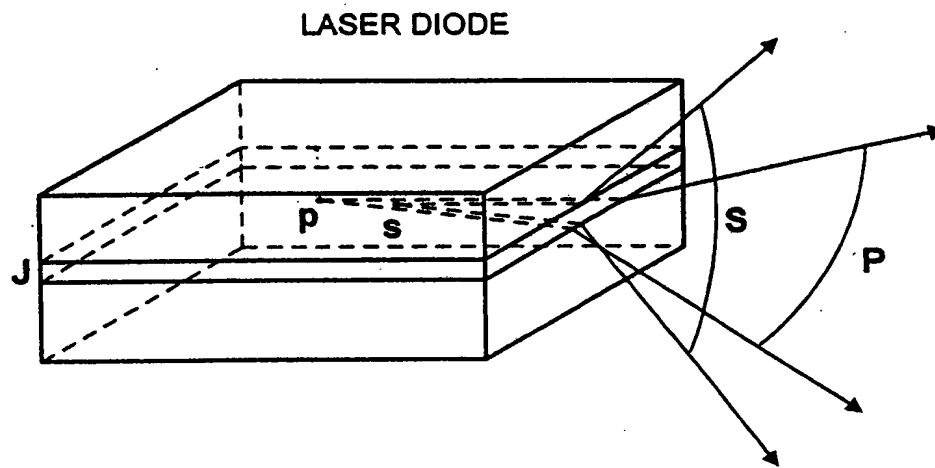
$\theta_r$  = REFERENCE BEAM ANGLE OF INCIDENCE

FIG. 19F





## ASTIGMATIC DIFFERENCE IN A LASER DIODE



**s** = EFFECTIVE SOURCE OF WAVEFRONT PERPENDICULAR TO JUNCTION

**p** = EFFECTIVE SOURCE OF WAVEFRONT PARALLEL TO JUNCTION

**S** = EXTERNAL WAVEFRONT PERPENDICULAR TO JUNCTION

**P** = EXTERNAL WAVEFRONT PARALLEL TO JUNCTION

**J** = DIOD JUNCTION LAYERS

**FIG. 20**

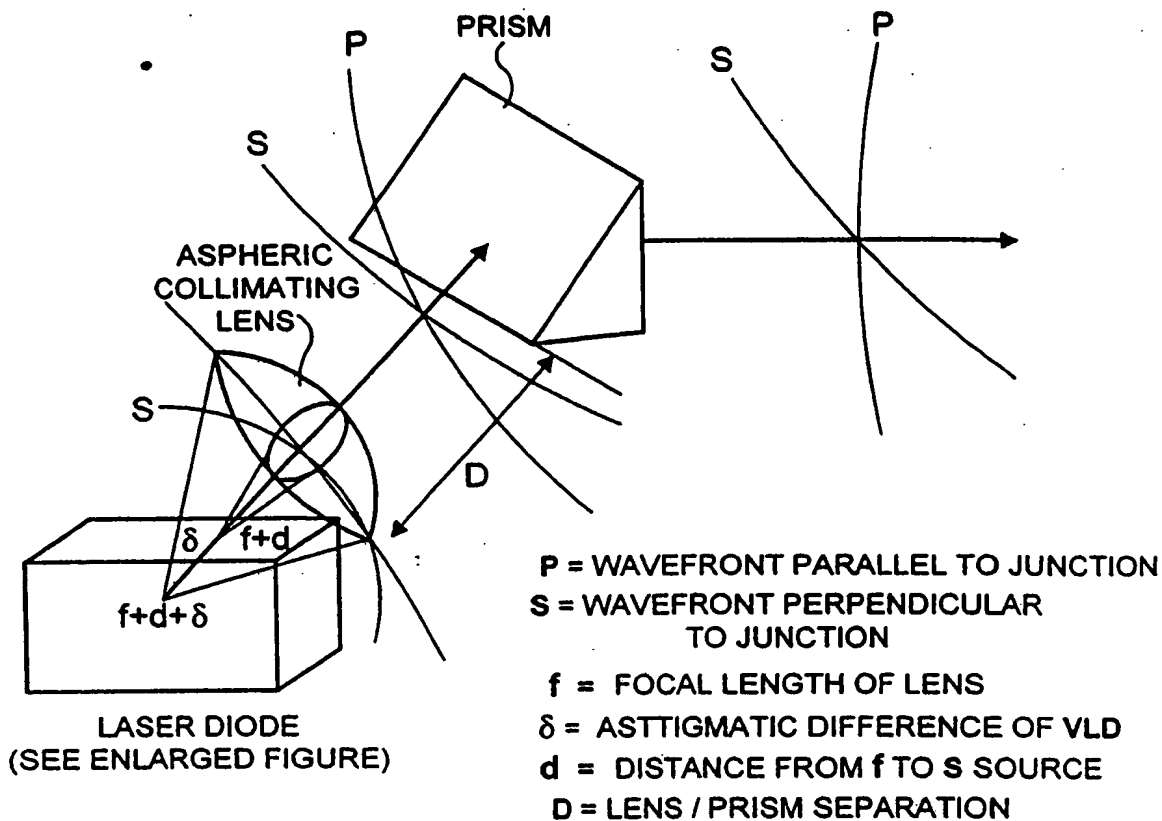


FIG. 20A

CIRCULARIZATION AND ASTIGMATISM ELIMINATION

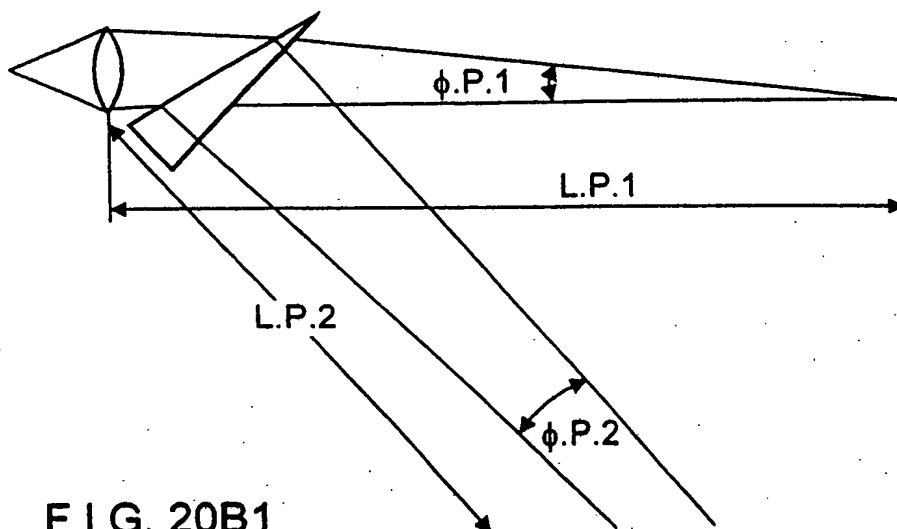
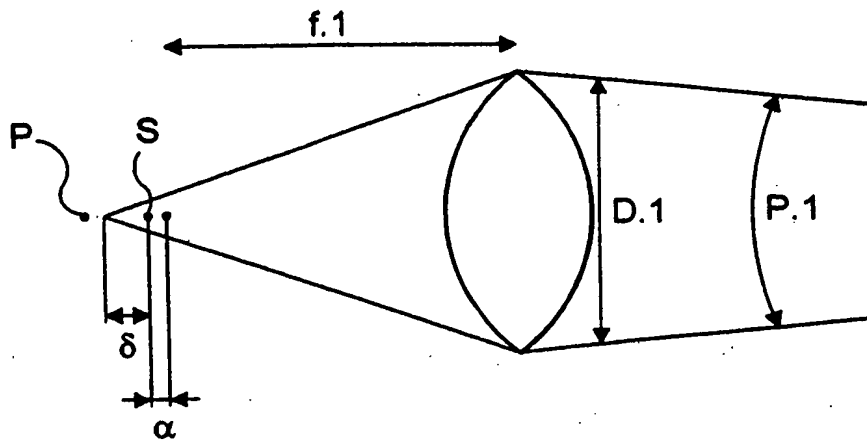


FIG. 20B1

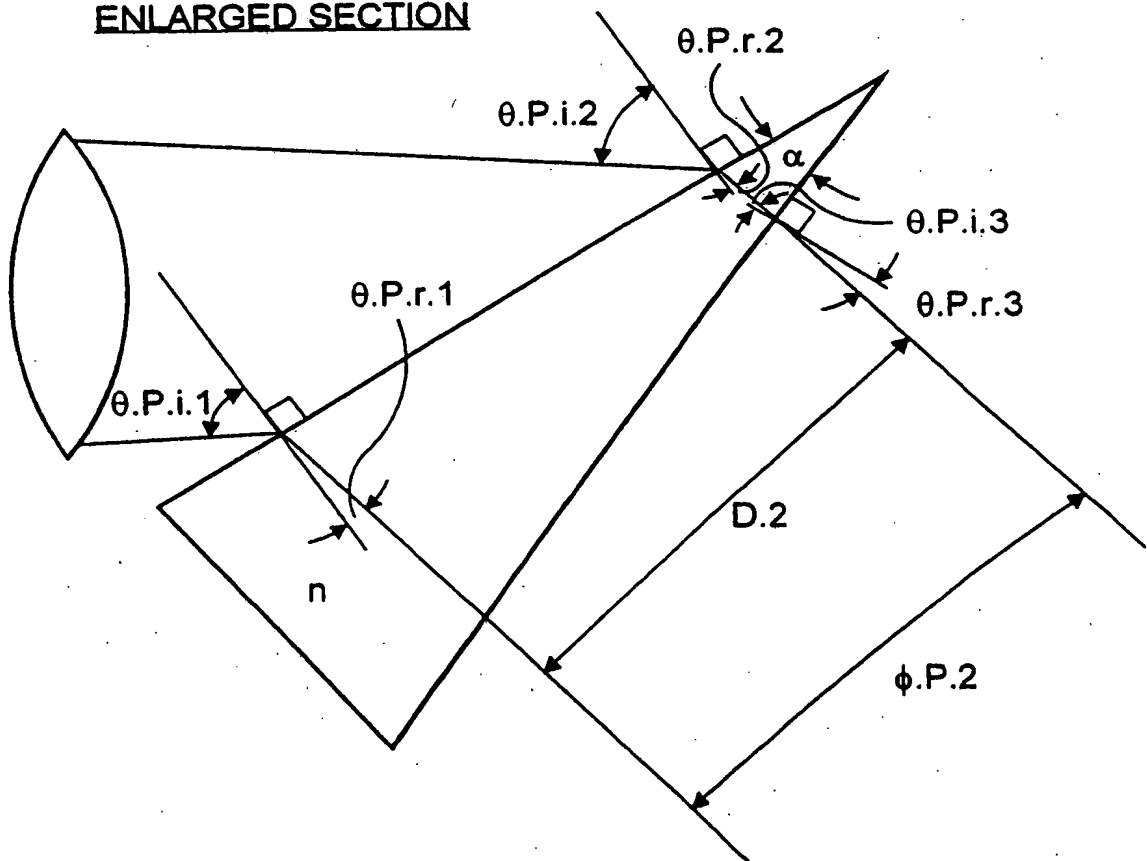


ENLARGED SECTION



F I G. 20B2

ENLARGED SECTION



F I G. 20B3



**ANALYSIS OF ASTIGMATIC DIFFERENCE REDUCTION WITH A  
CIRCULARIZING PRISM FOR THE GENERAL CASE WHERE  
BOTH S AND P BEAMS ARE CONVERGING.**

- f.1 = FOCAL LENGTH OF COLLIMATING LENS**  
**d = DISTANCE FROM FOCAL POINT OF COLLAMATING LENS TO S-BEAM  
SOURCE**  
 **$\delta$  = ASTIGMATIC DIFFERENCE OF LASER DIODE**  
**D.1 = P- BEAM DIAMETER LEAVING COLLIMATING LENS**  
**D.2 = EXPANDED P- BEAM DIAMETER LEAVING PRISM**  
**M = BEAM EXPANSION FACTOR = D.2 / D.1**  
**n = REFRACTIVE INDEX OF PRISM MATERIAL**  
 **$\theta$ .P.i.1 = ANGLE OF INCIDENCE OF LOWER PORTION OF CONVERGING  
P-BEAM AT PRISM**  
 **$\theta$ .P.i.2 = ANGLE OF INCIDENCE OF UPPER PORTION OF CONVERGING  
P-BEAM AT PRISM**  
 **$\phi$ .P.1 = CONVERGENCE OF P- BEAM LEAVING COLLIMATING LENS**  
 **$\phi$ .S.1 = CONVERGENCE OF S- BEAM LEAVING COLLIMATING LENS**  
 **$\phi$ .P.2 = CONVERGENCE OF P- BEAM LEAVING PRISM**  
 **$\phi$ .S.1 =  $\phi$ .S.1 = CONVERGENCE OF S- BEAM LEAVING PRISM**  
**L.P.1 = IMAGE DISTANCE FOR P SOURCE IMAGED BY COLLIMATING LENS**  
**L.P.2 = IMAGE DISTANCE FOR P SOURCE AFTER INSERTING PRISM**  
**L.S.1 = IMAGE DISTANCE FOR S SOURCE IMAGED BY COLLIMATING LENS**  
**L.S.2 = L.S.1 = IMAGE DISTANCE FOR S SOURCE AFTER INSERTING PRISM**  
 **$\theta$ .P.r.1 = ANGLE OF REFRACTION OF LOWER PORTION OF CONVERGING  
P-BEAM IN PRISM**  
 **$\theta$ .P.r.2 = ANGLE OF REFRACTION OF UPPER PORTION OF CONVERGING  
P-BEAM IN PRISM**  
 **$\alpha$  = PRISM APEX ANGLE =  $\theta$ .P.r.1 (BY DESIGN FOR CONVENIENCE )**  
 **$\theta$ .P.i.3 = ANGLE OF INCIDENCE OF UPPER PORTION OF CONVERGING  
P-BEAM AT SECOND SURFACE OF PRISM =  $\theta$ .P.r.1 -  $\theta$ .P.r.2 =  
=  $\alpha$  -  $\theta$ .P.r.2**  
 **$\theta$ .P.r.3 = ANGLE OF REFRACTION OF UPPER PORTION OF CONVERGING  
P-BEAM LEAVING SECOND SURFACE OF PRISM =  $\phi$ .P.2**

**F I G. 20C**

**ASSUMED VALUE OF FIXED PARAMETERS:**

$$\text{deg} = \frac{\pi}{180}$$

**n := 1.72 (REFRACTIVE INDEX OF SF10 GLASS AT 675 mm.)**

**f<sub>1</sub> := 4.5 mm**

**$\delta$  := .01 mm**

**D<sub>1</sub> := 1 mm**

**$\theta$ <sub>P.i.1</sub> := 78 deg**

**VARIABLE PARAMETER:**

**d := .00000000001, .00001, ... .001 mm**

**F I G. 20C1**



$$(1) L_{P.1}(d) := \frac{f_1^2}{d + \delta} \quad (2) L_{S.1}(d) := \frac{f_1^2}{d}$$

$$(3) \phi_{P.1}(d) := \text{atan} \left[ \frac{D_1}{L_{P.1}(d)} \right]$$

$$(4) \phi_{S.1}(d) := \text{atan} \left[ \frac{D_1}{L_{S.1}(d)} \right]$$

$$(5) M := \frac{\cos \left[ \text{asin} \left[ \frac{\sin [\theta_{P.i.1}]}{n} \right] \right]}{\cos [\theta_{P.i.1}]} \quad M = 3.9563$$

$$(6) D_2 := M D_1 \quad D_2 = 3.9563$$

$$(7) \theta_{P.i.2}(d) := \theta_{P.i.1} - \phi_{P.1}(d)$$

$$(8) \theta_{P.r.1} := \text{asin} \left[ \frac{\sin [\theta_{P.i.1}]}{n} \right] \quad \theta_{P.r.1} = 34.659 \text{ deg}$$

$$(9) \alpha := \theta_{P.r.1} \quad \alpha = 34.659 \text{ deg}$$

$$(10) \theta_{P.r.2}(d) := \text{asin} \left[ \frac{\sin [\theta_{P.i.2}(d)]}{n} \right]$$

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F I G. 20D



$$(11) \theta_{P.i.3}(d) := \theta_{P.r.1} - \theta_{P.r.2}(d)$$

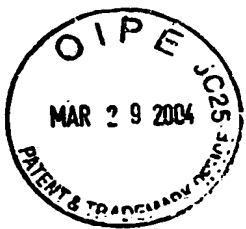
$$(12) \theta_{P.r.3}(d) := \text{asin} [ n \sin [\theta_{P.i.3}(d)] ]$$

$$(13) \phi_{P.2}(d) := \theta_{P.r.3}(d)$$

$$(14) L_{P.2}(d) := \frac{D_2}{\tan [\phi_{P.2}(d)]}$$

$$(15) L_{S.2}(d) := L_{S.1}(d)$$

FIG. 20D1

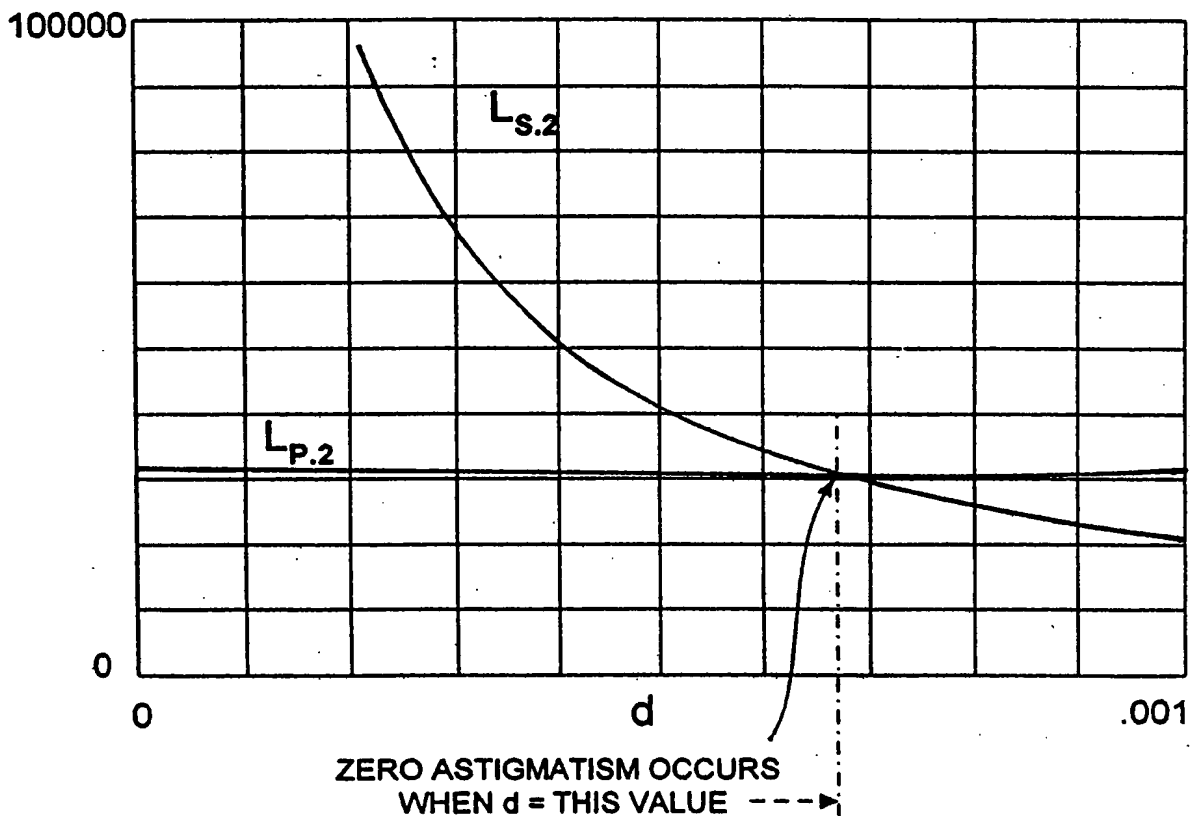


**S AND P IMAGE DISTANCES IN THE IMAGE PLANE OF THE COLLIMATING LENS AS A FUNCTION OF THE DISTANCE FROM THE FOCAL POINT OF THE COLLIMATING LENS TO THE S SOURCE. PRISM PLACED AFTER THE COLLIMATING LENS.  $\theta_{P.I.1}$  IS THE ANGLE OF INCIDENCE OF THE LOWER PORTION OF THE P-BEAM ON THE HYPOTENUSE OF THE PRISM.  $\delta$  IS THE VLD ASTIGMATIC DIFFERENCE.**

**S AND P IMAGE LOCATIONS - COLLIMATING LENS AND PRISM ONLY**

$n = 1.72$        $f_1 = 4.5 \text{ mm}$        $\theta_{P.I.1} = 78 \text{ deg}$        $\delta = 0.01 \text{ mm}$

$L_{P.2}(d), L_{S.2}(d)$



$d := .00068338 \text{ mm}$

$L_{P.2}(d) = 2.9632 \cdot 10^{-4} \text{ mm}$        $L_{S.2}(d) = 2.9632 \cdot 10^{-4} \text{ mm}$

**FIG. 20E**

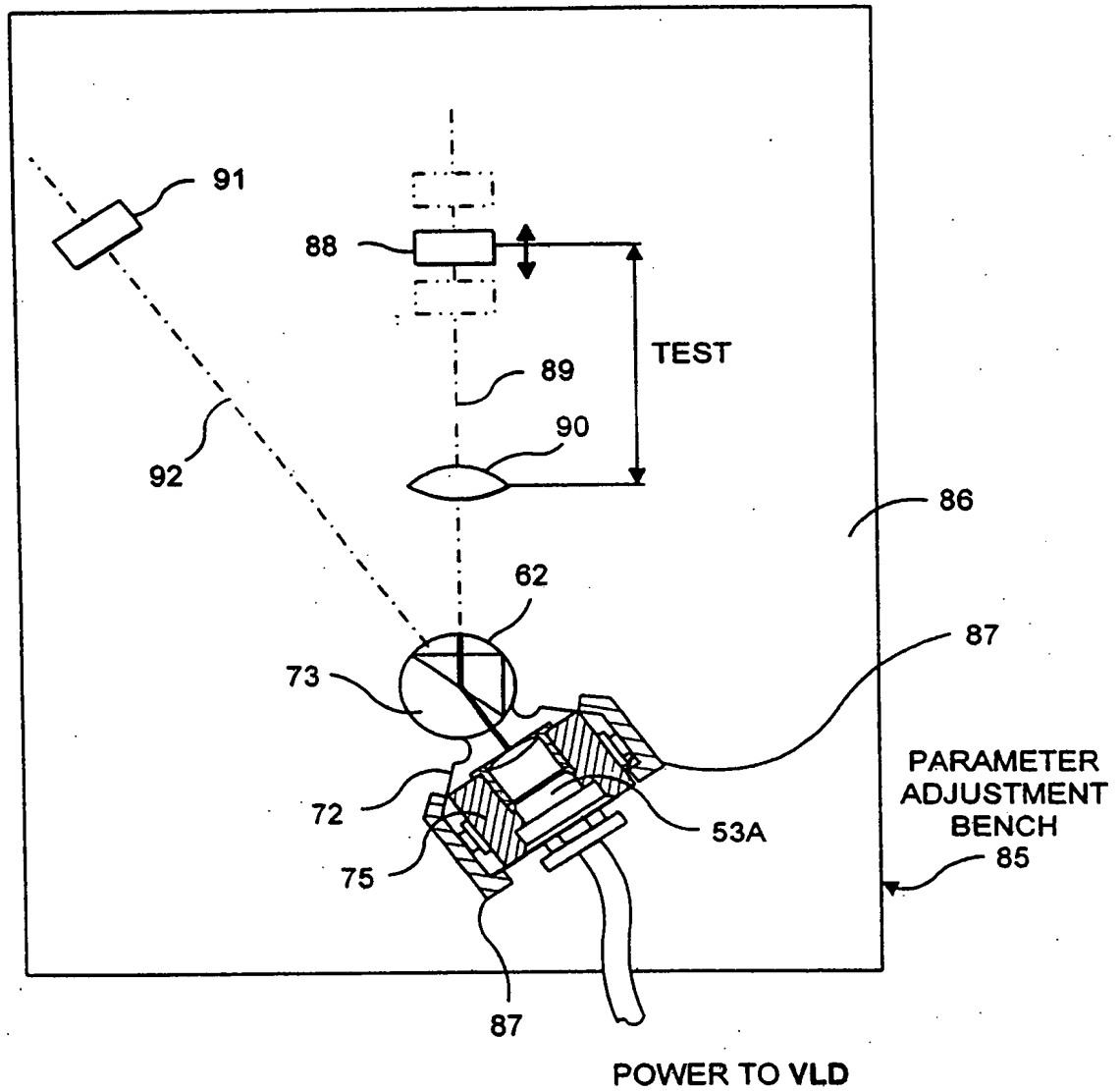


FIG. 21A



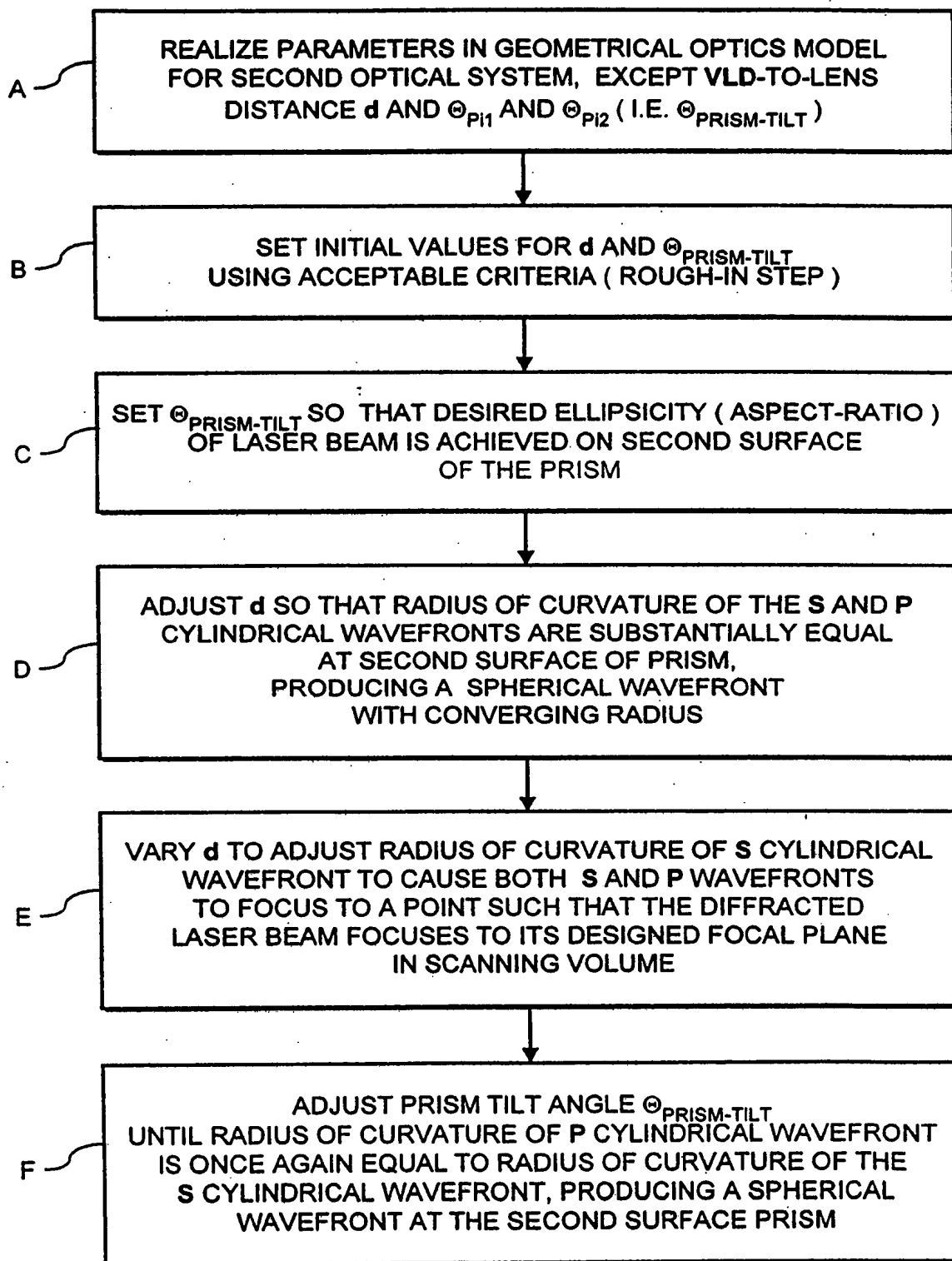
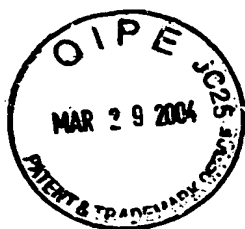


FIG. 21B

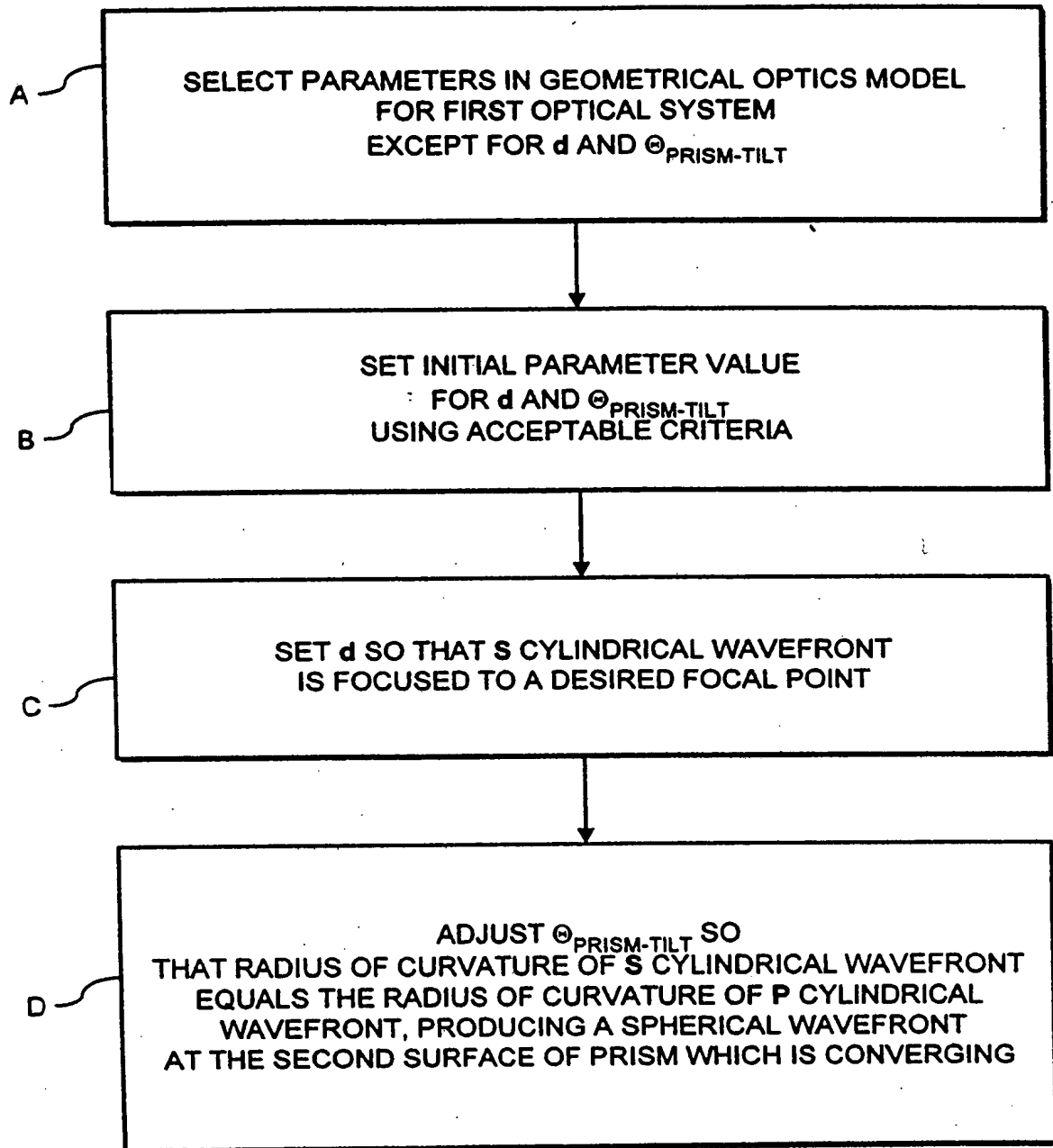
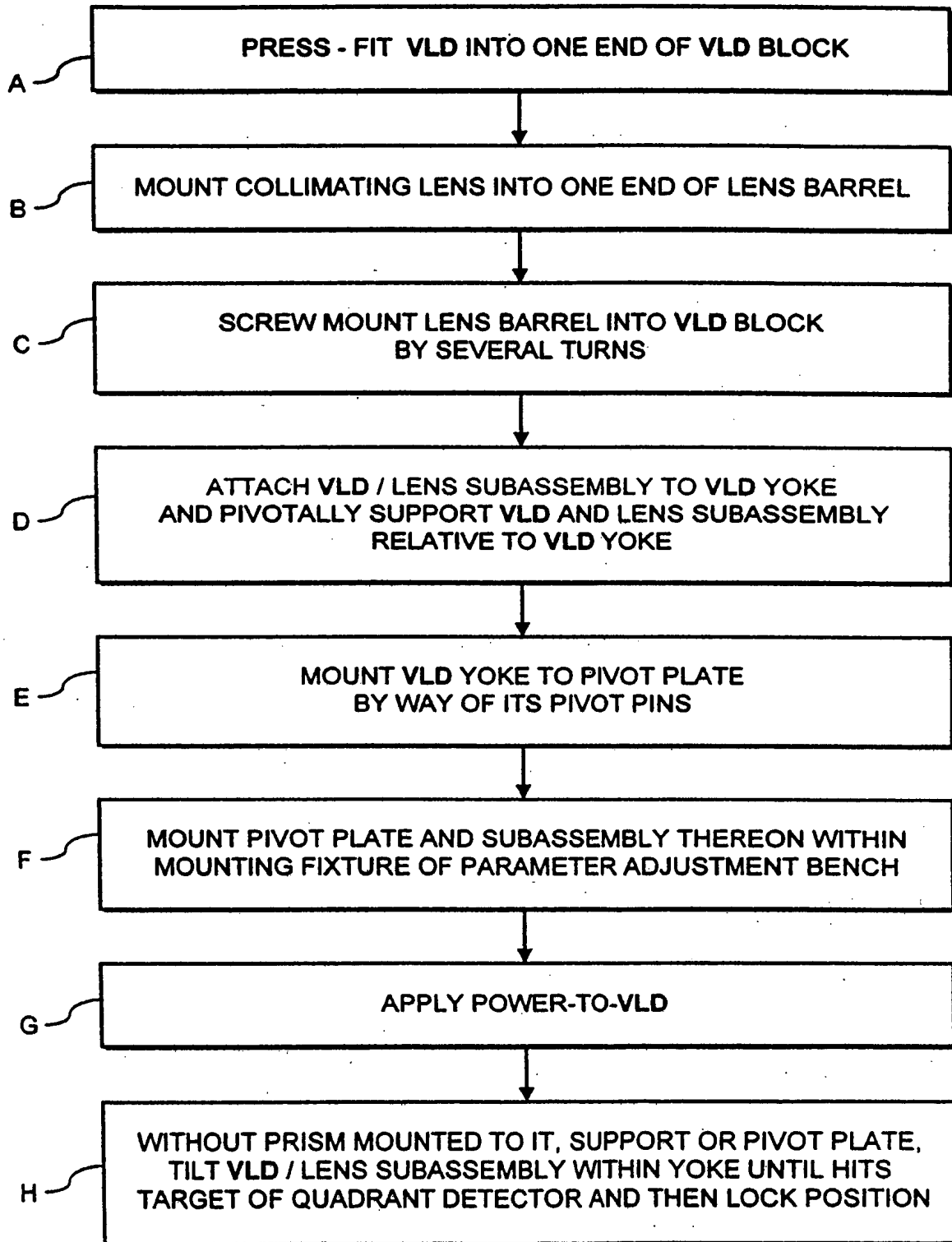


FIG. 21C



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FIG. 21C1

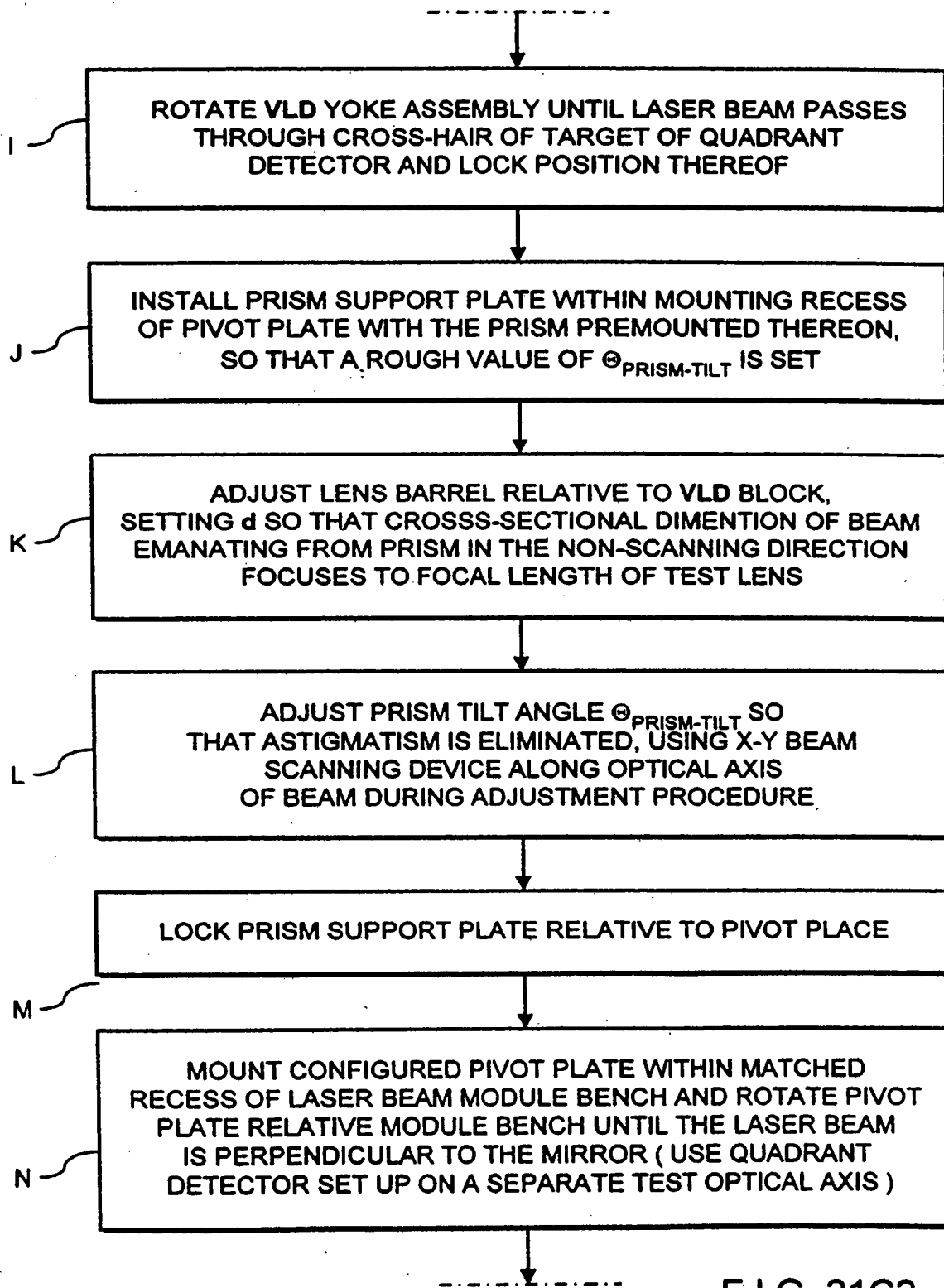


FIG. 21C2

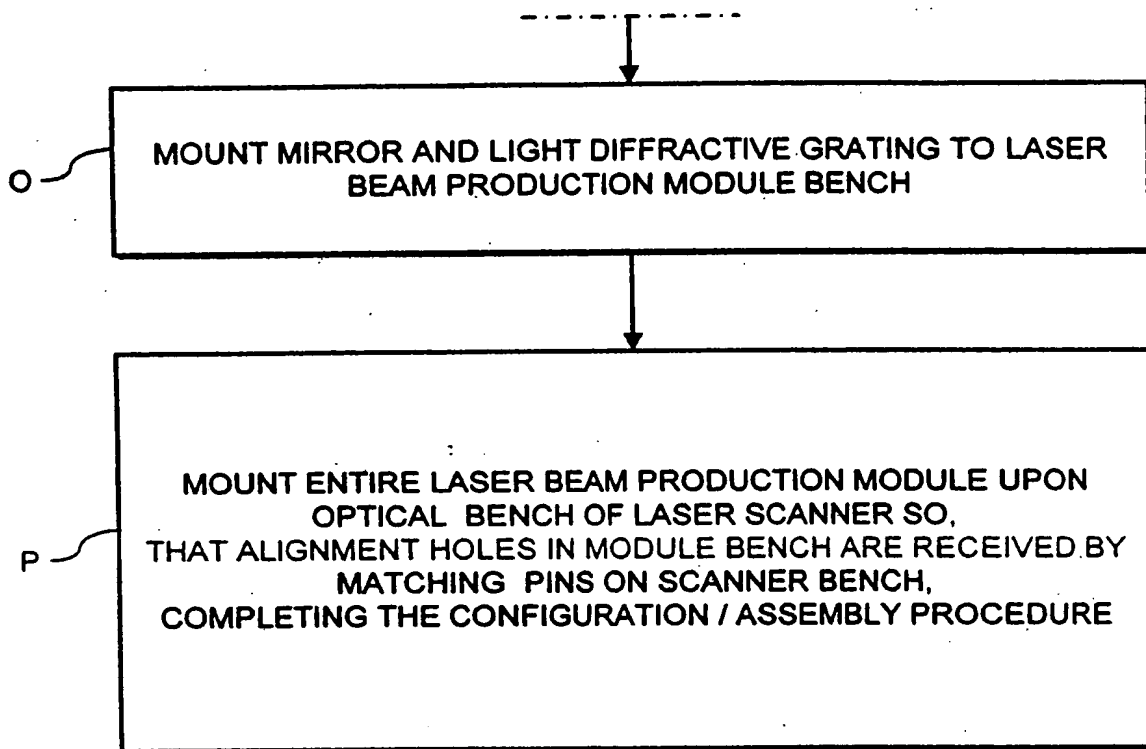


FIG. 21C3

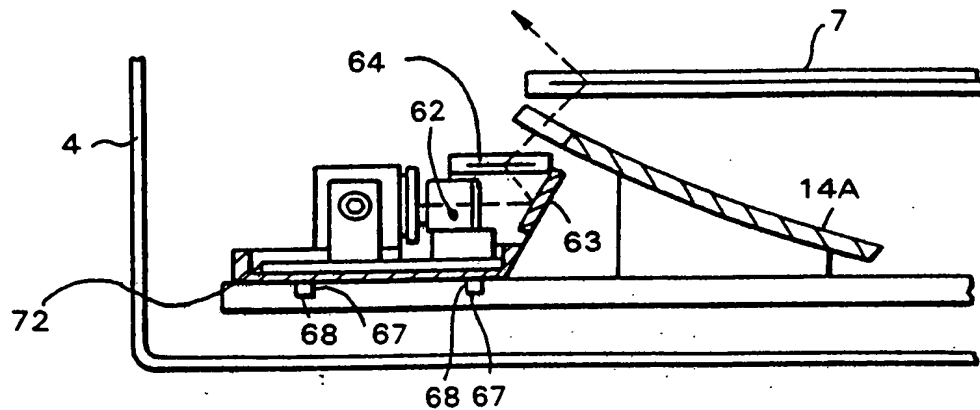


FIG. 21D

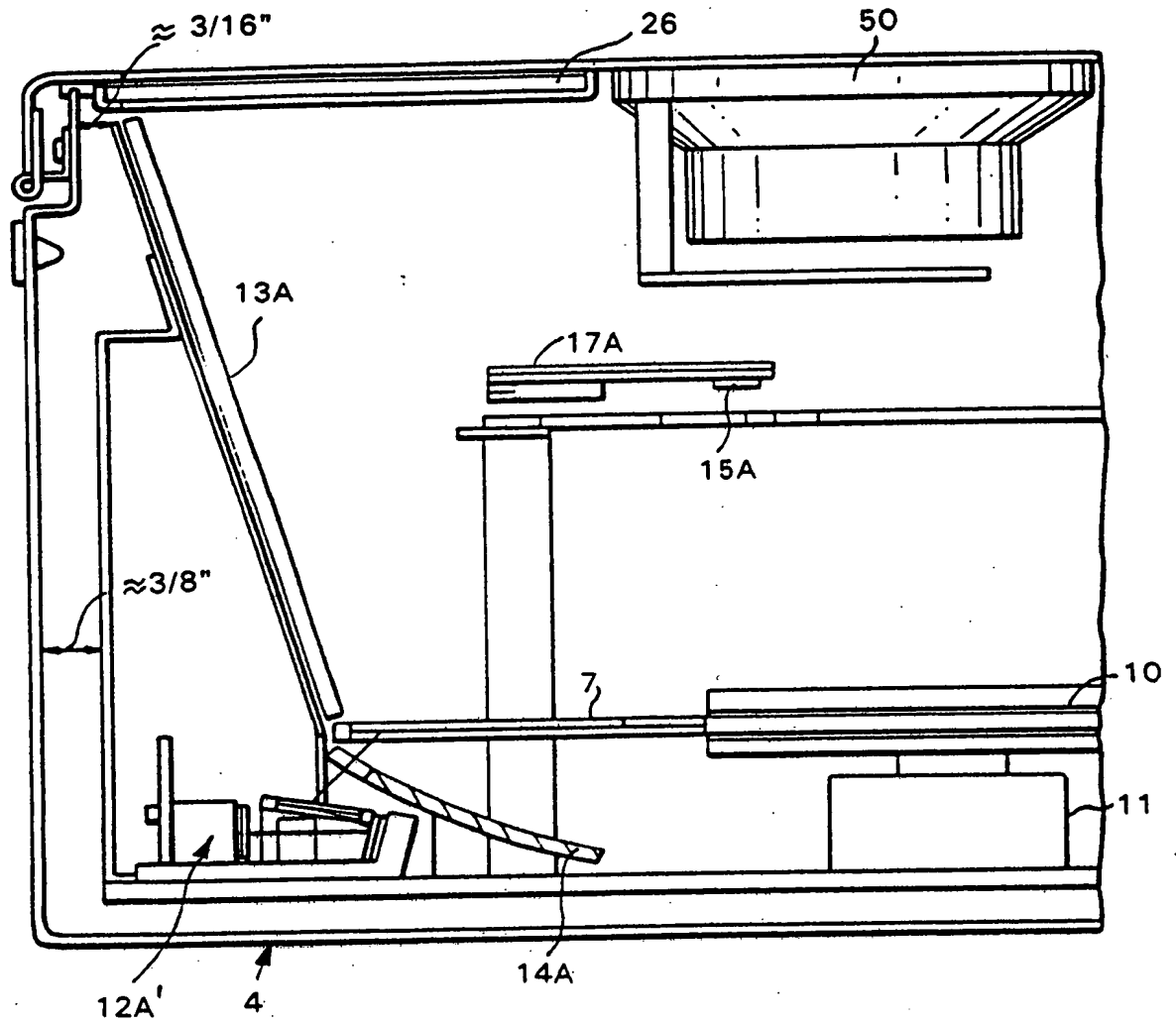


FIG. 22

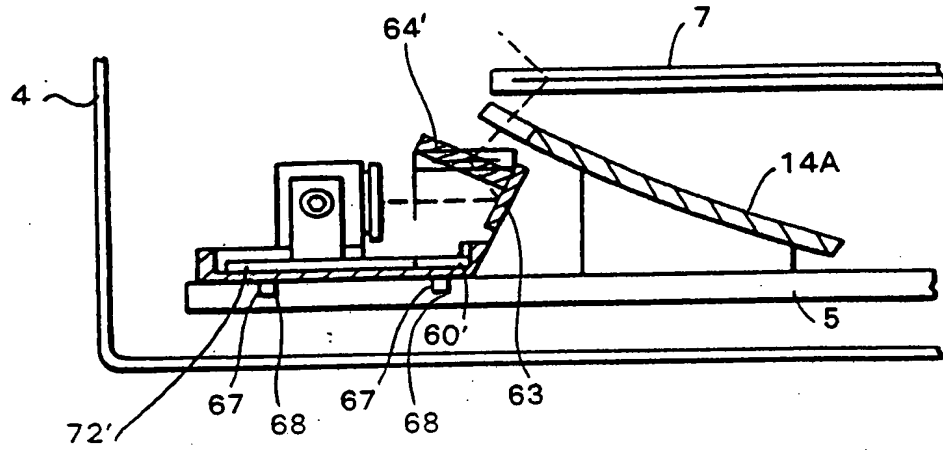


FIG. 23

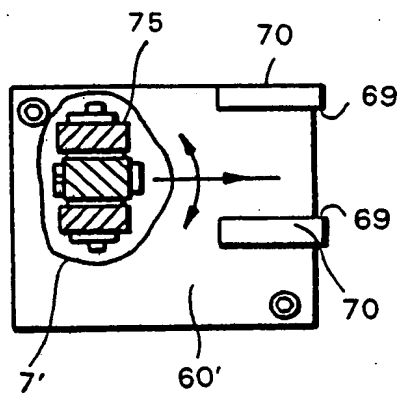


FIG. 23A



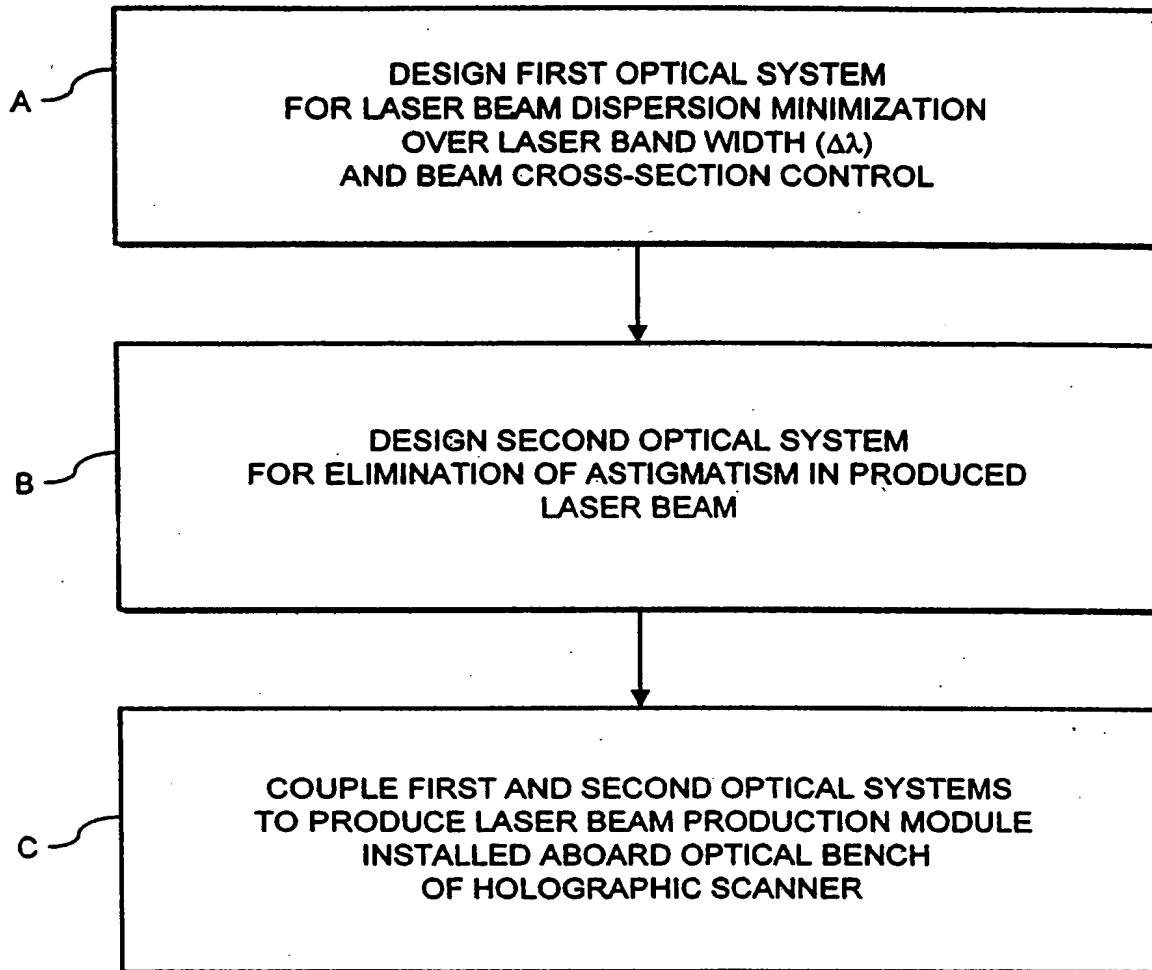


FIG. 24

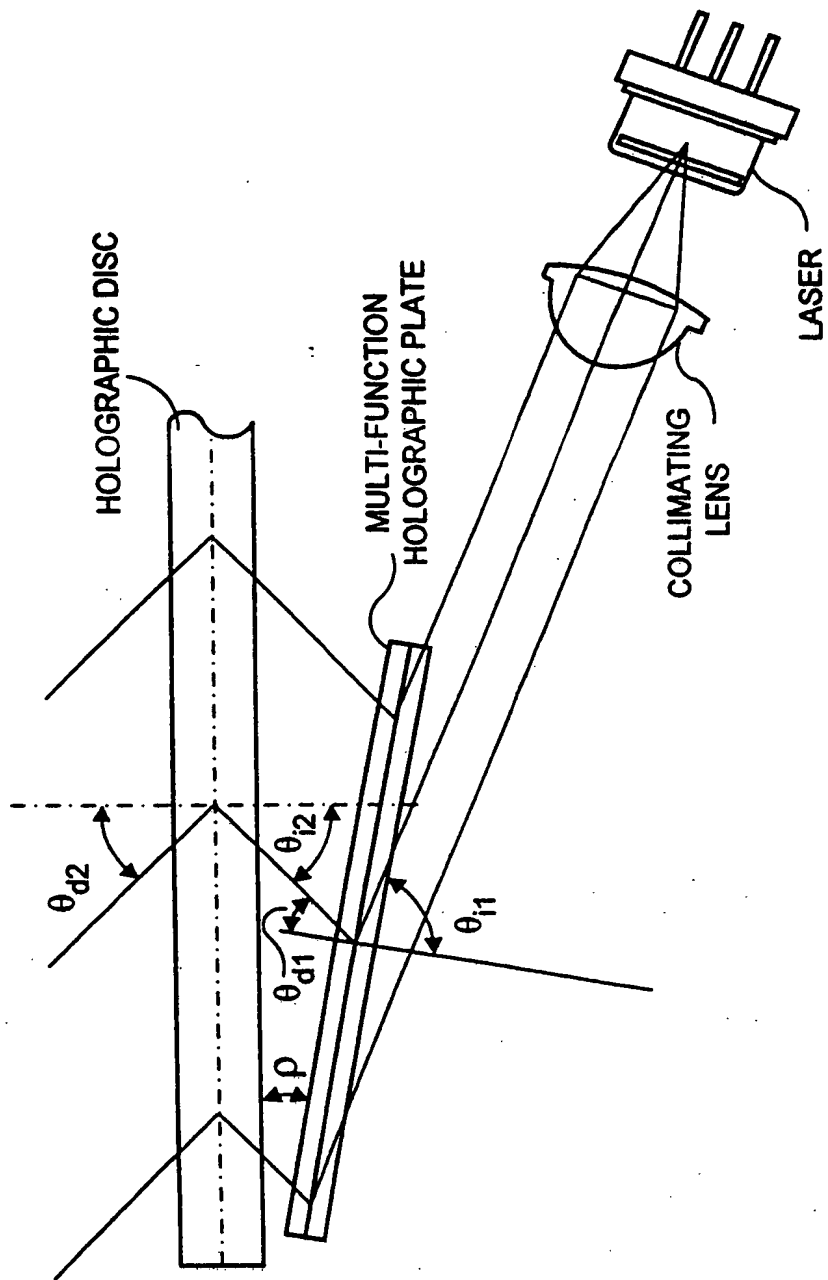
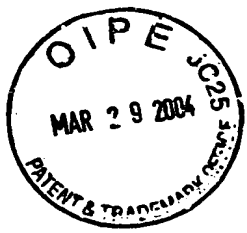


FIG. 25A



ANALYSIS OF THE MULTI-FUNCTION HOLOGRAPHIC PLATE. THIS ANALYSIS WILL DETERMINE THE ANGLE OF INCIDENCE AND ANGLE OF DIFFRACTION AND ORIENTATION ANGLE, RELATIVE TO THE HOLOGRAPHIC DISC, FOR A PRE-DISC HOLOGRAPHIC PLATE THAT SIMULTANEOUSLY ACCOMPLISHES ALL OF THE FUNCTIONS OF BEAM CIRCULARIZATION, ELIMINATION OF DISPERSION AND ELIMINATION OF ASTIGMATISM. ( THE ELIMINATION OF ASTIGMATISM IS ACTUALLY ACCOMPLISHED BY ADJUSTING THE LASER / COLLIMATION LENS SEPARATION AFTER THE BEAM EXPANSION RATIO IS ESTABLISHED FOR THE CIRCULARIZING FUNCTION. ) THE MULTI-FUNCTION HOLOGRAPHIC PLATE IS PLACED BETWEEN THE COLLIMATING LENS AND HOLOGRAPHIC DISC.

A DESIRED BEAM EXPANSION RATIO IS SELECTED AND THE ANGLES OF INCIDENCE AND DIFFRACTION FOR THE HOLOGRAPHIC DISC ARE GIVEN. WAVELENGTH IS ALSO GIVEN. THE FINAL RESULT IS A SINGLE GRAPH CONTAINING TWO PLOTS OF THE ANGLE OF INCIDENCE VS. MULTI-FUNCTION PLATE ORIENTATION ANGLE FOR TWO SITUATIONS - OBTAINING THE DESIRED BEAM EXPANSION RATIO AND OBTAINING ZERO DISPERSION, WHERE THESE TWO CURVES INTERSECT, BOTH REQUIREMENTS WILL BE MET SIMULTANEOUSLY.

- D.1 =** BEAM DIAMETER LEAVING COLLIMATING LENS
- D.2 =** EXPANDED BEAM DIAMETER LEAVING MULTI-FUNCTION HOLOGRAPHIC PLATE
- M =** BEAM EXPANSION FACTOR =  $D.2 / D.1$
- d.2 =** GRATING SPACING OF THE HOLOGRAPHIC DISC ( microns )
- d.1 =** GRATING SPACING OF THE MULTI-FUNCTION HOLOGRAPHIC PLATE ( microns )
- $\theta.i.2$  =** ANGLE OF INCIDENCE OF BEAM AT HOLOGRAPHIC DISC
- $\theta.d.2$  =** ANGLE OF DIFFRACTION OF BEAM LEAVING HOLOGRAPHIC DISC
- $\theta.i.1.M$  =** ANGLE OF INCIDENCE OF BEAM AT HOLOGRAPHIC MULTI-FUNCTION PLATE THAT WILL PROVIDE THE DESIRED BEAM EXPANSION RATIO, M
- $\theta.i.1.D$  =** ANGLE OF INCIDENCE OF BEAM AT HOLOGRAPHIC MULTI-FUNCTION PLATE THAT WILL PROVIDE ZERO DISPERSION FOR THE BEAM LEAVING THE HOLOGRAPHIC DISC
- $\theta.d.1.M$  =** ANGLE OF DIFFRACTION OF BEAM LEAVING MULTI-FUNCTION PLATE THAT WILL PROVIDE THE DESIRED BEAM EXPANSION RATIO, M
- $\theta.d.1.D$  =** ANGLE OF DIFFRACTION OF BEAM LEAVING MULTI-FUNCTION PLATE THAT WILL PROVIDE ZERO DISPERSION FOR THE BEAM LEAVING THE HOLOGRAPHIC DISC
- $\rho$  =** ORIENTATION ANGLE OF MULTI-FUNCTION PLATE RELATIVE TO THE HOLOGRAPHIC DISC
- $\lambda$  =** WAVELENGTH OF LASER BEAM ( microns )

**F I G. 25B**



**ASSUMED PARAMETERS:**

$M := 3$  BEAM EXPANSION RATIO  $\text{deg} = \frac{\pi}{180}$

$\lambda := .670$  microns WAVELENGTH OF LASER

$\theta_{i.2} := 43$  deg :ANGLE OF INCIDENCE AT HOLOGRAPHIC DISC

$\theta_{d.2} := 37$  deg ANGLE OF DIFFRACTION AT HOLOGRAPHIC DISC

$\rho := -5$  deg,  $-5.1$  deg, ...,  $-12$  deg

**F I G. 25B1**



$$(1) \quad d_2 := \frac{\lambda}{\sin [\theta_{i,2}] + \sin [\theta_{d,2}]} \quad \text{GRATING SPACING FOR HOLOGRAPHIC DISC}$$

$$(2) \quad \theta_{i,1.M}(\rho) := \arccos \left[ \frac{\cos [\theta_{i,2} + \rho]}{M} \right] \quad \begin{array}{l} \text{ANGLE OF} \\ \text{INCIDENCE} \\ \text{AT PLATE} \\ \text{TO GIVE} \\ \text{THE DESIRED} \\ \text{BEAM} \\ \text{EXPANSION} \\ \text{RATIO} \end{array}$$

$$(3) \quad \theta_{d,1.M}(\rho) := \theta_{i,2} + \rho \quad \text{CORRESPONDING ANGLE OF DIFFRACTION}$$

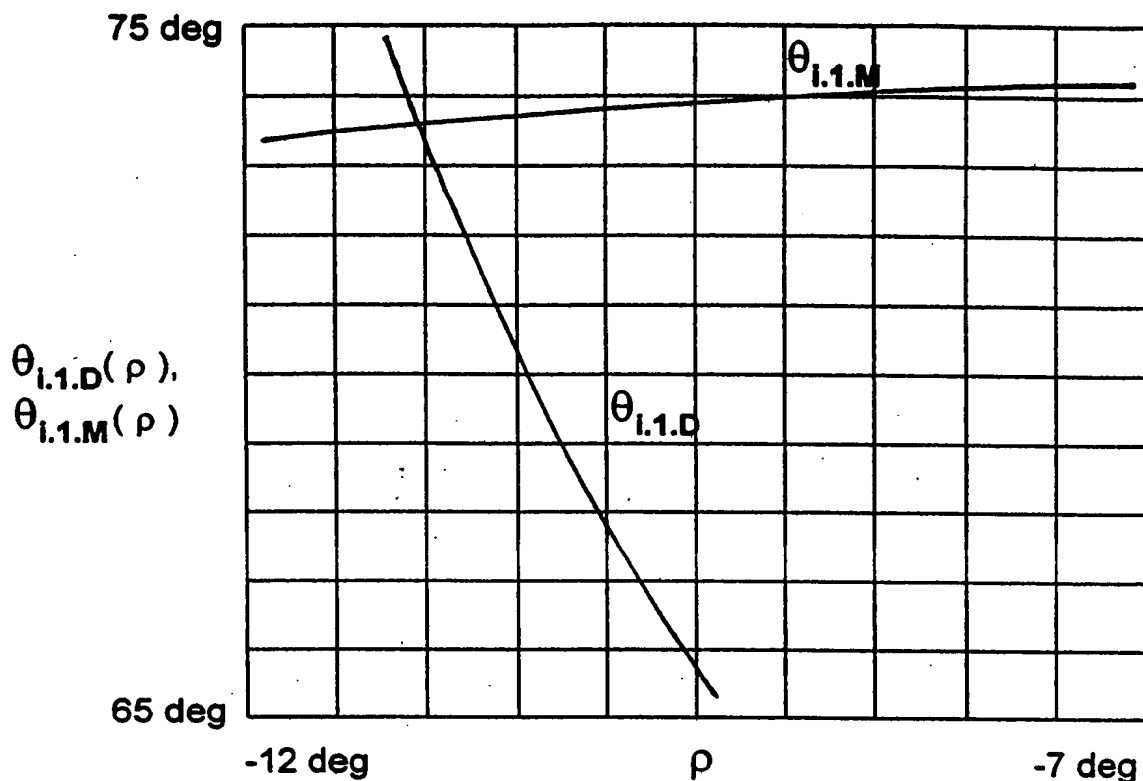
$$(4) \quad d_{1.M}(\rho) := \left[ \frac{\lambda}{\sin [\theta_{i,1.M}(\rho)] + \sin [\theta_{d,1.M}(\rho)]} \right] \quad \text{RESULTANT GRATING SPACING}$$

$$(5) \quad \theta_{i,1.D}(\rho) := \arcsin \left[ \lambda \frac{\cos [\theta_{i,2} + \rho]}{d_2 \cos [\theta_{i,2}]} - \sin [\theta_{i,2} + \rho] \right] \quad \begin{array}{l} \text{ANGLE OF} \\ \text{INCIDENCE} \\ \text{AT PLATE} \\ \text{TO GIVE} \\ \text{ZERO} \\ \text{DISPERSION} \end{array}$$

$$(6) \quad \theta_{d,1.D}(\rho) := \theta_{i,2} + \rho \quad \text{CORRESPONDING ANGLE OF DIFFRACTION}$$

$$(7) \quad d_{1.D}(\rho) := \left[ \frac{\lambda}{\sin [\theta_{i,1.D}(\rho)] + \sin [\theta_{d,1.D}(\rho)]} \right] \quad \text{RESULTANT GRATING SPACING}$$

F I G. 25C



$\rho := -11.01\text{deg}$

ORIENTATION ANGLE, RELATIVE TO THE  
HOLOGRAPHIC DISC, OF THE MULTI-  
FUNCTION HOLOGRAPHIC PLATE FOR ZERO  
DISPERSION AND A BEAM EXPANSION RATIO  
OF 3.0

**FIG. 25D**

CONSTRUCTION PARAMETERS FOR THE MULTI- FUNCTION  
HOLOGRAPHIC PLATE AT 670 nm WAVELENGTH

$$\theta_{i.1.M}(\rho) = 73.57777674 \text{ deg} \quad \theta_{i.1.D}(\rho) = 73.54631956 \text{ deg}$$

$$\theta_{d.1.M}(\rho) = 31.99 \text{ deg} \quad \theta_{d.1.D}(\rho) = 31.99 \text{ deg}$$

$$d_{1.M}(\rho) = 0.44997378 \text{ microns} \quad d_{1.D}(\rho) = 0.45002074 \text{ microns}$$

**FIG. 25E**



## GEOMETRICAL OPTICS MODEL FOR BRAGG SENSITIVITY ANALYZER

CORRECTED, COMPENSATED, CIRCULARIZED  
OUTPUT BEAM

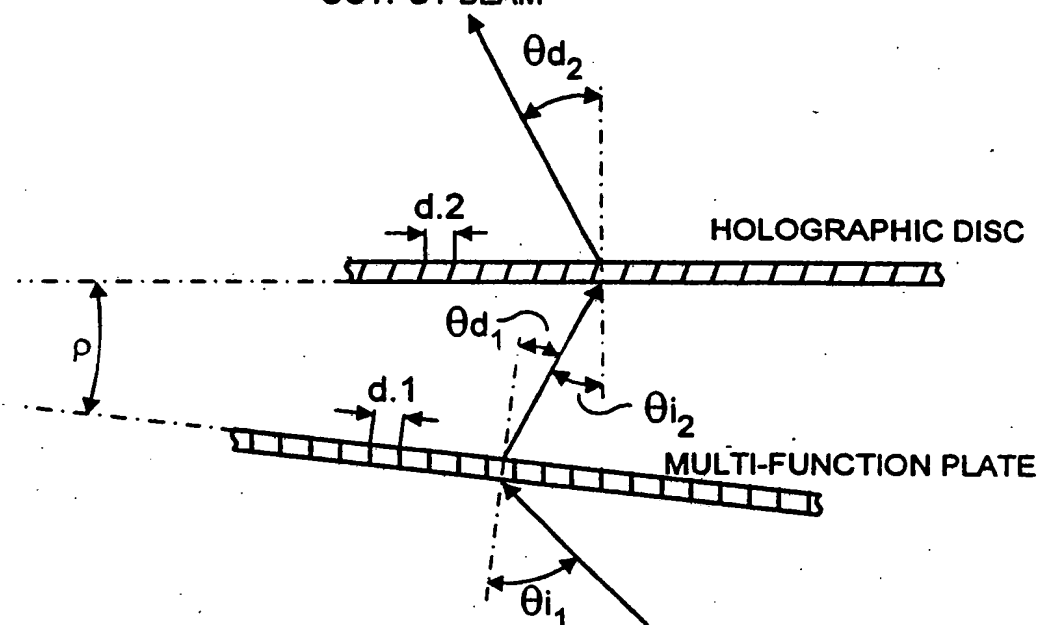


FIG. 26



## ANALYSIS OF THE DISPERSION OF THE MULTI-FUNCTION HOLOGRAPHIC PLATE

THIS ANALYSIS WILL SHOW THE VARIATION OF DIFFRACTION ANGLE FOR THE BEAM LEAVING THE HOLOGRAPHIC DISC WHEN THE MULTI-FUNCTION HOLOGRAPHIC PLATE IS USED WITH THE CONSTRUCTION PARAMETERS AS CALCULATED ABOVE AND WITH THE ORIENTATION ANGLE, RELATIVE TO THE HOLOGRAPHIC DISC, AS ALSO CALCULATED ABOVE.

$\theta_{i.1}$  = ANGLE OF INCIDENCE FOR MULTI-FUNCTION PLATE ( FIXED - SEE ABOVE )

$\theta_{d.c.1}$  = CONSTRUCTION ANGLE OF DIFFRACTION OF MULTI-FUNCTION PLATE ( FIXED - SEE ABOVE )

$\theta_{d.1}$  = ANGLE OF DIFFRACTION OF MULTI-FUNCTION PLATE ( VARIES WITH WAVELENGTH ) :

$\theta_{d.c.1}$  = CONSTRUCTION ANGLE OF DIFFRACTION OF HOLOGRAPHIC DISC ( FIXED - SEE  $\theta_{d.2}$  IN ABOVE ANALYSIS )

$\theta_{d.2}$  = ANGLE OF DIFFRACTION OF BEAM LEAVING HOLOGRAPHIC DISC ( VARIES WITH WAVELENGTH )

$\lambda$  = WAVELENGTH ( IN AIR )

$\lambda_c$  = CONSTRUCTION WAVELENGTH ( = .670 microns )

$d.1$  = GRATING SPACING IN MULTI-FUNCTION PLATE ( FIXED - SEE ABOVE )

$\rho$  = TILT ANGLE OF MULTI-FUNCTION PLATE RELATIVE TO HOLOGRAPHIC DISC ( FIXED - SEE ABOVE )

### FIG. 27A

$$\lambda_c := .670 \text{ microns}$$

$$\theta_{d.c.2} := 37 \text{ deg}$$

$$\theta_{i.2} := 43 \text{ deg}$$

$$\theta_{i.1} := \theta_{i.1.M}(\rho)$$

$$\theta_{d.c.1} := \theta_{i.2} + \rho$$

$$\lambda := .650, .6501, \dots, .690$$

$$\theta_{d.c.1} = 31.99 \text{ deg}$$

### FIG. 27B





$$(1) \quad d_1 := \frac{\lambda_c}{\sin [\theta_{i,1}] + \sin [\theta_{d,c,1}]} \text{ microns}$$

$$d_1 = 0.44997378$$

$$(2) \quad \theta_{d,1}(\lambda) := \text{asin} \left[ \left[ \frac{\lambda}{d_1} \right] - \sin [\theta_{i,1}] \right]$$

$$(3) \quad M := \left[ \frac{\cos [\theta_{d,c,1}]}{\cos [\theta_{i,1}]} \right] \quad M = 3$$

$$(4) \quad \theta_{d,2}(\lambda) :=$$

$$= \text{asin} \left[ \frac{\lambda}{d_2} - \sin \left[ \text{asin} \left[ \frac{\lambda}{d_1} - \sin [\theta_{i,1}] \right] - \rho \right] \right]$$

FIG. 27C



DISPERSION CHARACTERISTIC GRAPH AND SAMPLE VALUES

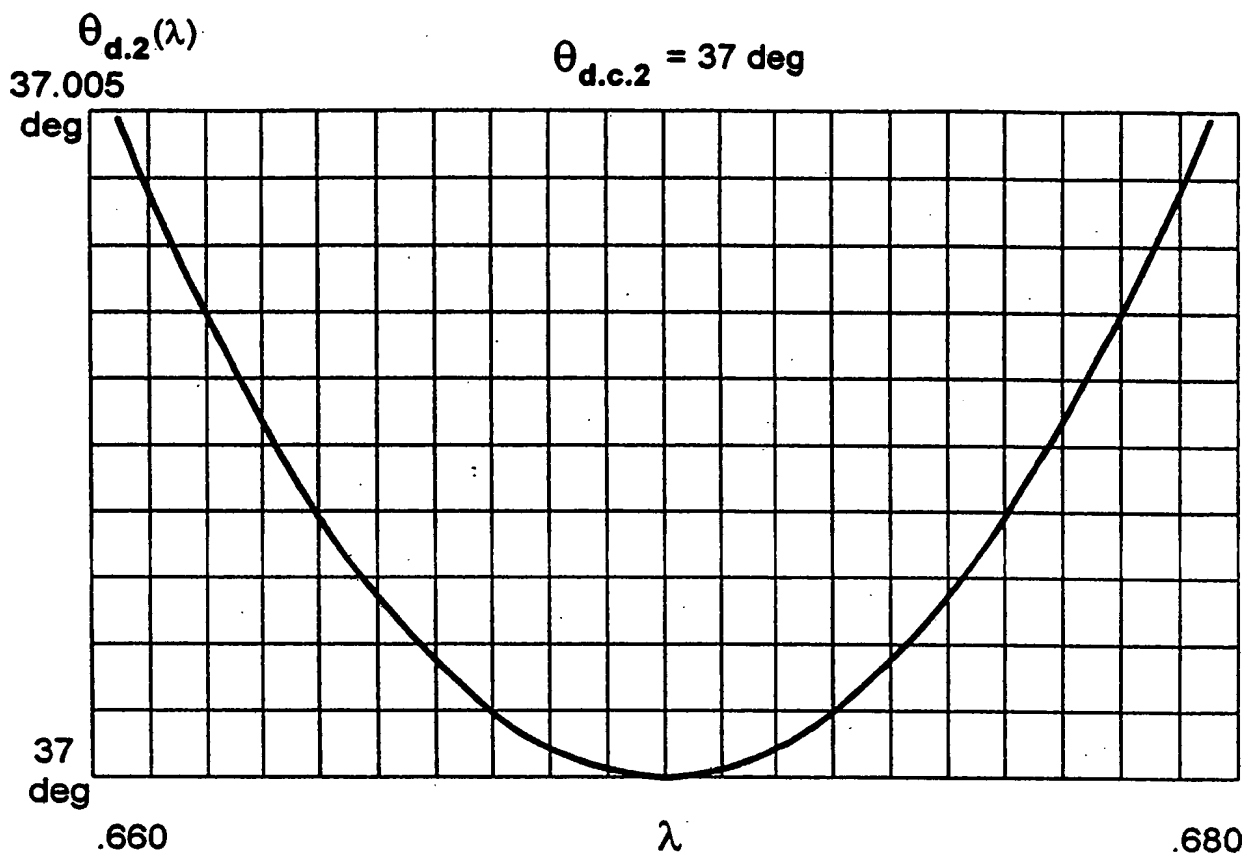
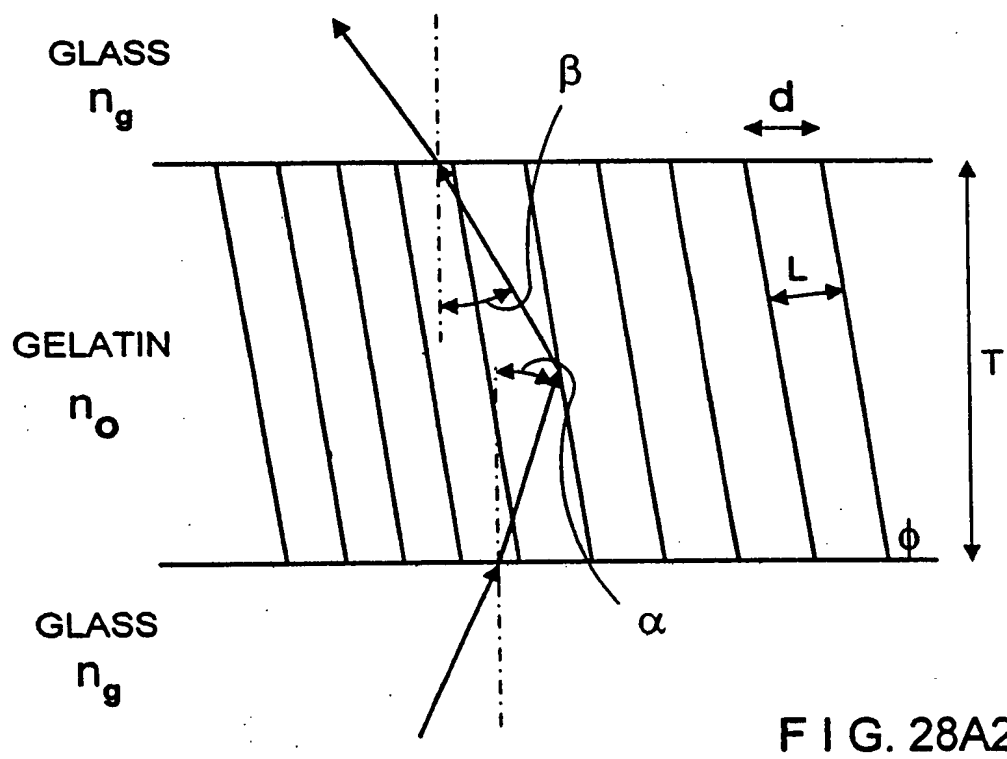
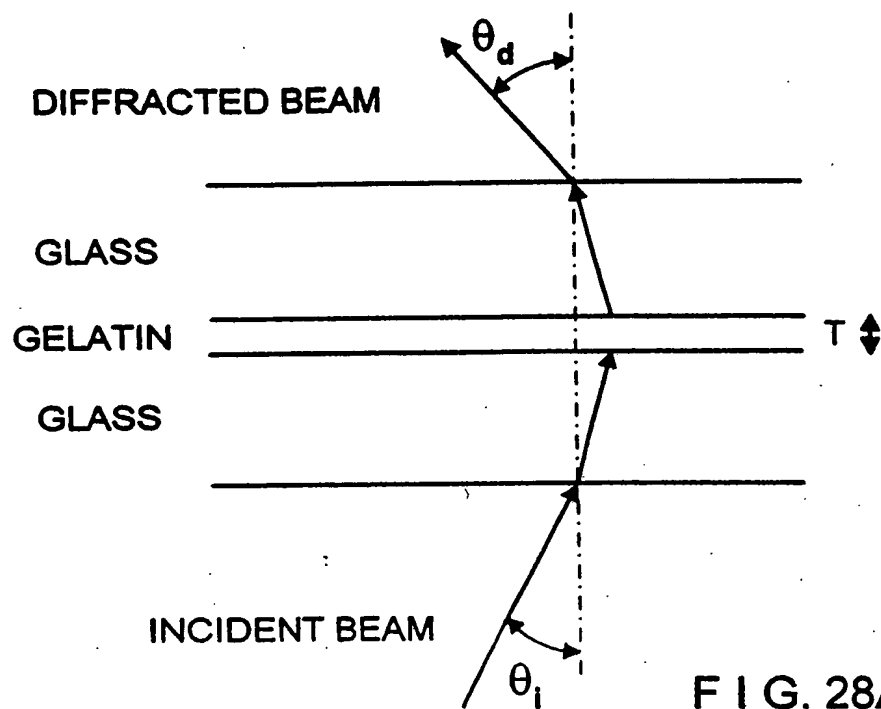


FIG. 27D

$\lambda$	$:= .660 \text{ microns}$	$\theta_{d.2}(\lambda) = 37.00560129 \text{ deg}$
$\lambda$	$:= .665 \text{ microns}$	$\theta_{d.2}(\lambda) = 37.00144699 \text{ deg}$
$\lambda$	$:= .670 \text{ microns}$	$\theta_{d.2}(\lambda) = 37 \text{ deg}$
$\lambda$	$:= .675 \text{ microns}$	$\theta_{d.2}(\lambda) = 37.00132623 \text{ deg}$
$\lambda$	$:= .680 \text{ microns}$	$\theta_{d.2}(\lambda) = 37.00549609 \text{ deg}$
$\delta\theta_{d.2}$	$:= \theta_{d.2}(.675) - \theta_{d.2}(.670)$	$\delta\theta_{d.2} = 0.00132623 \text{ deg}$

FIG. 27D1





CHANGE IN CONSTRUCTION BEAM ANGLES FOR A CHANGE IN WAVELENGTH BETWEEN CONSTRUCTION AND RECONSTRUCTION. THIS PROGRAM CALCULATES THE EXTERNAL ANGLE OF INCIDENCE AND EXTERNAL ANGLE OF DIFFRACTION FOR THE CONSTRUCTION WAVELENGTH WHEN THE EXTERNAL ANGLE OF INCIDENCE AND EXTERNAL ANGLE OF DIFFRACTION ARE GIVEN FOR THE RECONSTRUCTION WAVELENGTH. BRAGG CONDITION IS MAINTAINED IN BOTH CASES SO THAT THE BRAGG PLANE TILT IS UNCHANGED.

$$\text{deg} = \frac{\pi}{180}$$

$n_0 := 1.53$	AVERAGE REFRACTIVE INDEX OF THE MEDIUM BEFORE PROCESSING
$n_2 := 1.4$	AVERAGE REFRACTIVE INDEX OF THE MEDIUM AFTER PROCESSING
$\lambda_1 := .670$	RECONSTRUCTION WAVELENGTH (VISIBLE LASER DIODE)
$\lambda_2 := .488$	CONSTRUCTION WAVELENGTH (ARGON LASER)
$\theta_{i,1} := 77 \text{ deg}$	ANGLE OF INCIDENCE AT RECONSTRUCTION
$\theta_{d,1} := 31.5 \text{ deg}$	ANGLE OF DIFFRACTION AT RECONSTRUCTION

FIG. 28B

#### HOE CONSTRUCTION ANGLES AT SECOND WAVELENGTH

REFERENCE BEAM

OBJECT BEAM

$$\theta_{i,2} = \theta_R = 54.143 \text{ deg}$$

$$\theta_{d,2} = \theta_O = 15.915 \text{ deg}$$

FIG. 28D



$$(1) \alpha_1 := \text{asin} \left[ \frac{\sin [\theta_{i.1}]}{n_2} \right]$$

ANGLE OF INCIDENCE INSIDE  
THE MEDIUM AFTER PROCESSING

$$\alpha_1 = 44.105 \text{ deg}$$

$$(2) \beta_1 := \text{asin} \left[ \frac{\sin [\theta_{d.1}]}{n_2} \right]$$

ANGLE OF DIFFRACTION INSIDE  
THE MEDIUM AFTER PROCESSING

$$\beta_1 = 21.914 \text{ deg}$$

$$d := \frac{\lambda_1}{\sin [\theta_{i.1}] + \sin [\theta_{d.1}]}$$

$$d = 0.448 \text{ microns}$$

$$\frac{1000}{d} = 2.234 \cdot 10^3 \text{ lines per mm.}$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta_1 - \alpha_1}{2}$$

TILT ANGLE OF THE BRAGG PLANES

$$\phi = 101.086 \text{ deg}$$

$$(4) \theta_{0.1} := \alpha_1 + \frac{\pi}{2} - \phi$$

ANGLE RELATIVE TO THE BRAGG  
PLANES

$$\theta_{0.1} = 34.198 \text{ deg}$$

$$(6) L := \frac{\lambda_1}{2 n_2 \sin [\theta_{0.1}]}$$

SEPARATION OF THE BRAGG  
PLANES.

BRAGG CONDITION EQUATION.

$$L = 0.442 \text{ microns}$$

$$(7) \theta_{0.2} := \text{asin} \left[ \frac{\lambda_2}{2 n_0 L} \right]$$

ANGLE RELATIVE TO THE BRAGG  
PLANES FOR THE SECOND  
WAVELENGTH SATISFYING THE  
BRAGG CONDITION - BEFORE  
PROCESSING

$$\theta_{0.2} = 21.619 \text{ deg}$$

FIG. 28C1



$$(8) \alpha_2 := \theta_{0.2} + \phi - \frac{\pi}{2}$$

ANGLE OF INCIDENCE INSIDE  
THE MEDIUM FOR THE SECOND  
WAVELENGTH - BEFORE PROCESSING

$$\alpha_2 = 32.705 \text{ deg}$$

$$(9) \beta_2 := \alpha_2 + \pi - 2\phi$$

ANGLE OF DIFFRACTION INSIDE  
THE MEDIUM FOR THE SECOND  
WAVELENGTH - BEFORE PROCESSING

$$\beta_2 = 10.534 \text{ deg}$$

$$(10) \theta_R := \text{asin} [n_0 \sin [ \alpha_2 ]]$$

ANGLE OF INCIDENCE  
(REFERENCE BEAM) FOR THE  
SECOND WAVELENGTH -  
EXTERNAL

$$\theta_R = 54.143 \text{ deg}$$

$$(11) \theta_O := \text{asin} [n_0 \sin [ \beta_2 ]]$$

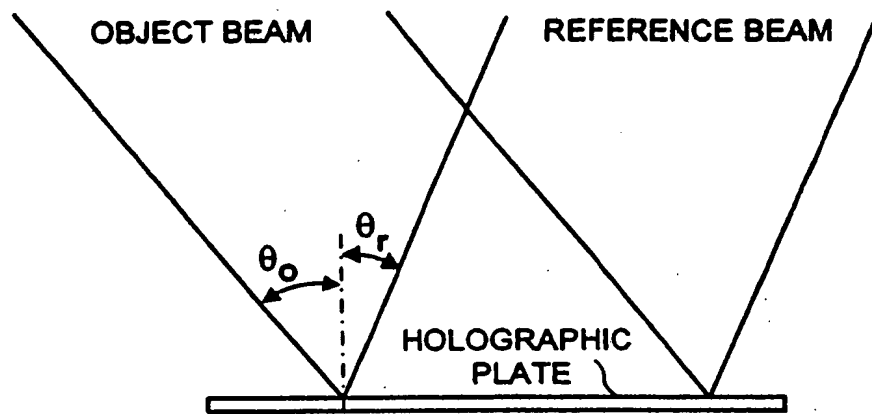
ANGLE OF DIFFRACTION  
(OBJECT BEAM) FOR THE  
SECOND WAVELENGTH -  
EXTERNAL

$$\theta_O = 15.915 \text{ deg}$$

FIG. 28C2



## CONSTRUCTION OF A MULTI-FUNCTION HOLOGRAPHIC PLATE



$\theta_o$  = OBJECT BEAM ANGLE OF INCIDENCE

$\theta_r$  = REFERENCE BEAM ANGLE OF INCIDENCE

FIG. 29

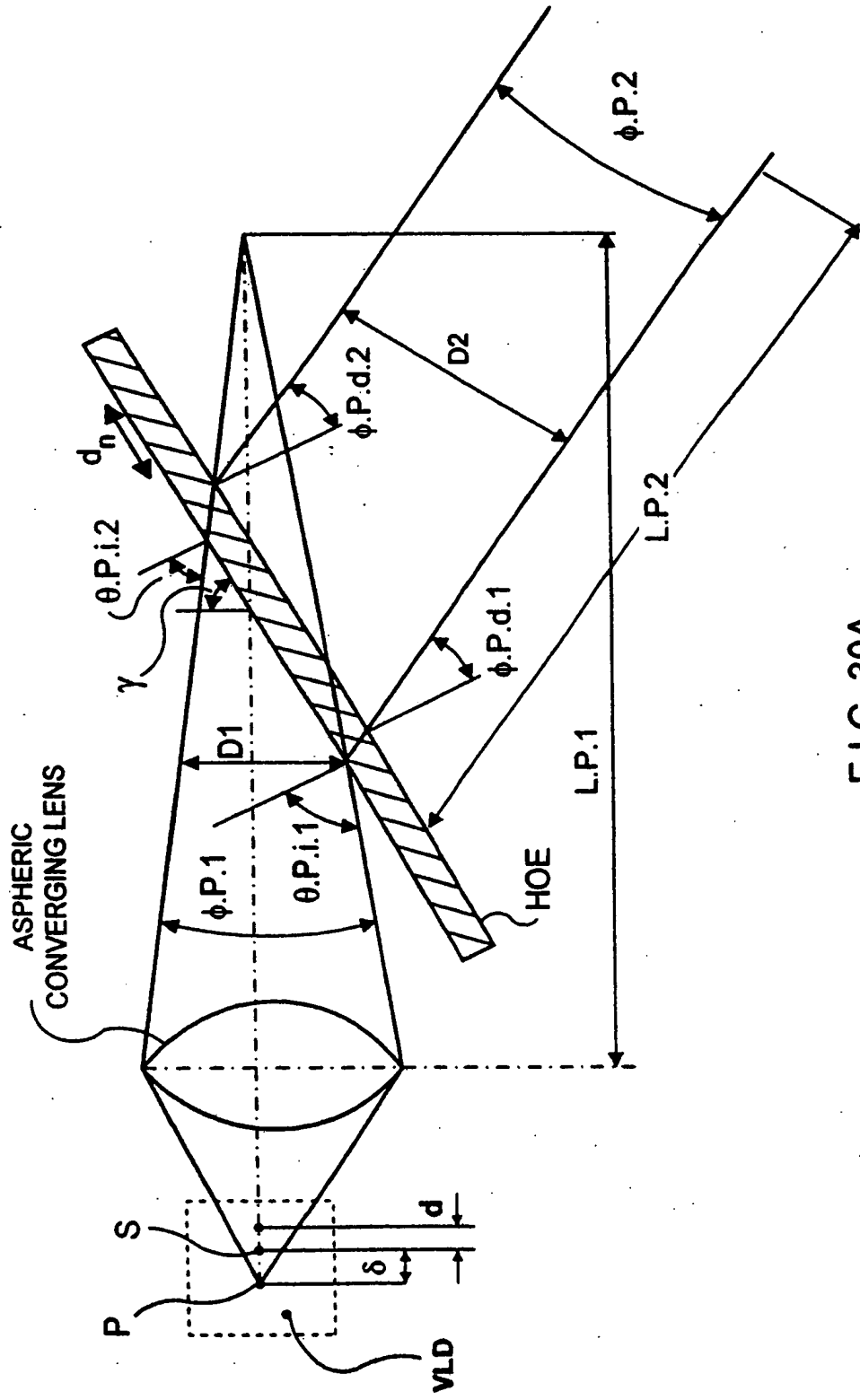
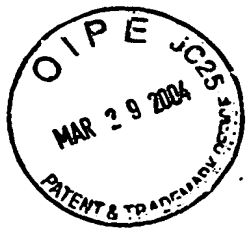
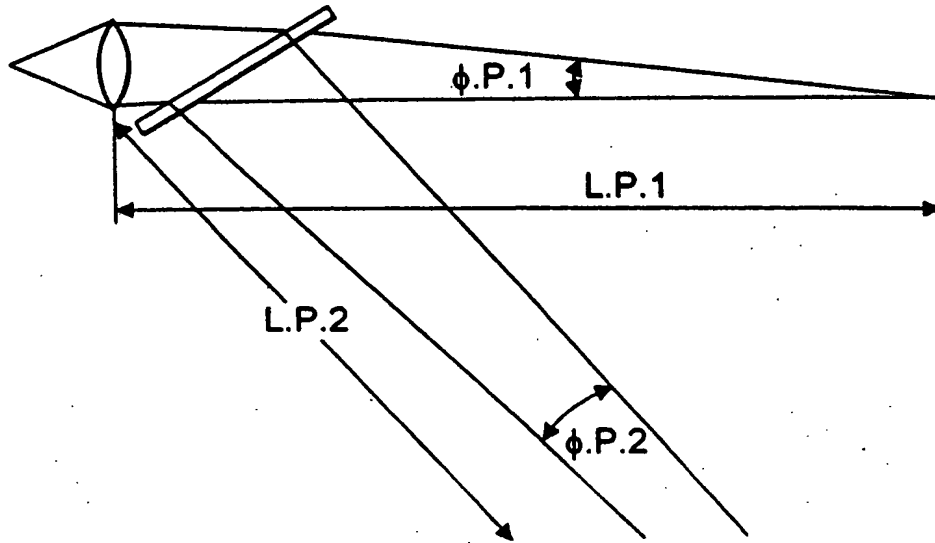


FIG. 30A





**CIRCULARIZATION AND ASTIGMATISM ELIMINATION**  
**WITH A HOE**



**F I G. 30A1**



ENLARGED SECTION

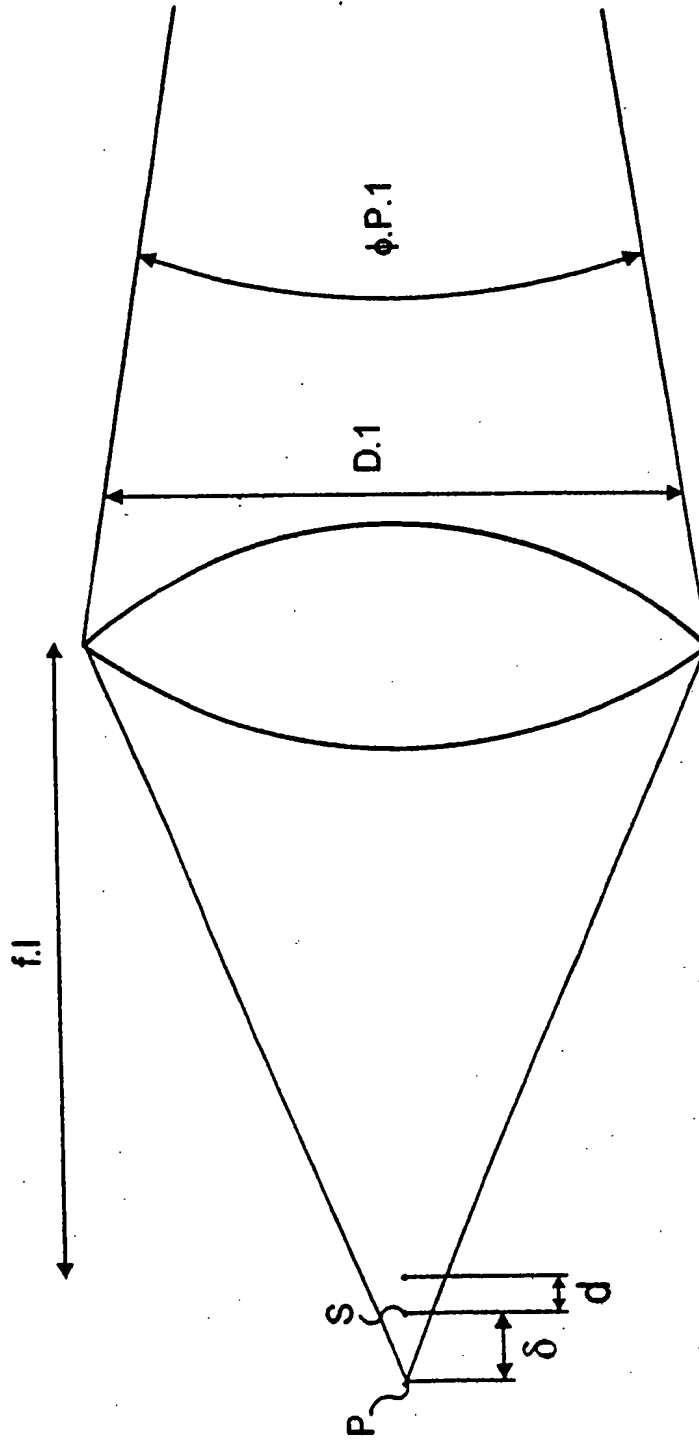
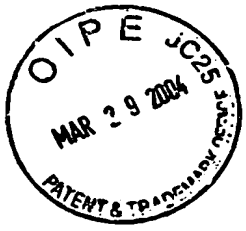
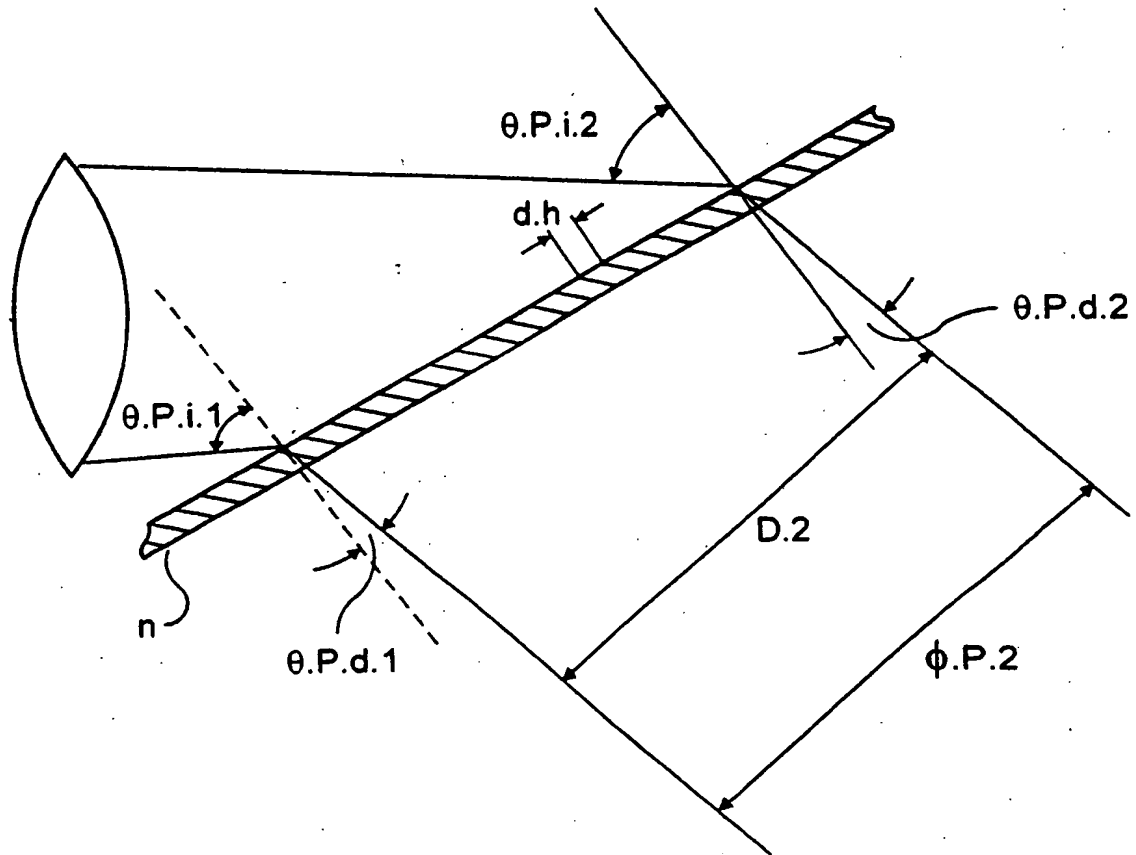


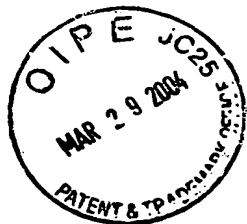
FIG. 30A2



**ENLARGED SECTION**



**FIG. 30A3**



**ANALYSIS OF ASTIGMATIC DIFFERENCE REDUCTION WITH A  
CIRCULARIZING HOLOGRAPHIC OPTICAL ELEMENTS ( HOE ) FOR  
GENERAL CASE WHERE BOTH S AND P BEAMS ARE  
CONVERGING.**

**THE HOE IN THIS CASE IS A SIMPLE, FIXED-SPATIAL-FREQUENCY  
HOLOGRAPHIC DIFFRACTION GRATING.**

- f.1 = FOCAL LENGTH OF COLLIMATING LENS**  
**d = DISTANCE FROM FOCAL POINT OF COLLAMATING LENS TO S-BEAM  
SOURCE**  
 **$\delta$  = ASTIGMATIC DIFFERENCE OF LASER DIODE**  
**D.1 = P- BEAM DIAMETER LEAVING COLLIMATING LENS**  
**D.2 = EXPANDED P- BEAM DIAMETER LEAVING HOE**  
**M = BEAM EXPANTION FACTOR = D.2 / D.1**  
**d.h = GRATING SPACING OF HOE GRATING ( mm )**  
 **$\theta$ .P.i.1 = ANGLE OF INCIDENCE OF LOWER PORTION OF CONVERGING  
P-BEAM AT HOE**  
 **$\theta$ .P.i.2 = ANGLE OF INCIDENCE OF UPPER PORTION OF CONVERGING  
P-BEAM AT HOE**  
 **$\phi$ .P.1 = CONVERGENCE OF P- BEAM LEAVING COLLIMATING LENS**  
 **$\phi$ .S.1 = CONVERGENCE OF S- BEAM LEAVING COLLIMATING LENS**  
 **$\phi$ .P.2 = CONVERGENCE OF P- BEAM LEAVING HOE**  
 **$\phi$ .S.1 =  $\phi$ .S.1 = CONVERGENCE OF S- BEAM LEAVING HOE**  
**L.P.1 = IMAGE DISTANCE FOR P SOURCE IMAGED BY COLLIMATING LENS**  
**L.P.2 = IMAGE DISTANCE FOR P SOURCE AFTER INSERTING HOE**  
**L.S.1 = IMAGE DISTANCE FOR S SOURCE IMAGED BY COLLIMATING LENS**  
**L.S.2 = L.S.1 = IMAGE DISTANCE FOR S SOURCE AFTER INSERTIG HOE**  
 **$\theta$ .P.d.1 = ANGLE OF DIFFRACTION OF LOWER PORTION OF CONVERGING  
P-BEAM AT HOE**  
 **$\theta$ .P.d.2 = ANGLE OF DIFFRACTION OF UPPER PORTION OF CONVERGING  
P-BEAM AT HOE**  
 **$\lambda$  = WAVELENGTH OF LASER BEAM**

**F I G. 30B**

**ASSUMED VALUE OF FIXED PARAMETERS:**

$$\text{deg} = \frac{\pi}{180}$$

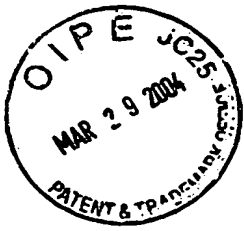
$$\lambda := .000670 \text{ mm} \quad \theta_{P.i.1} := 73.6 \text{ deg} \quad \theta_{P.d.1} := 32 \text{ deg}$$

$$f_1 := 4.5 \text{ mm} \quad D_1 := 1 \text{ mm} \quad \delta := .01 \text{ mm}$$

**VARIABLE PARAMETER:**

$$d := .00000000001, .00004, \dots .004 \text{ mm}$$

**F I G. 30B1**



$$d_h := \frac{\lambda}{\sin[\theta_{P.I.1}] + \sin[\theta_{P.I.1}]}$$

$$(1) L_{P.1}(d) := \frac{f_1^2}{d + \delta} \quad (2) L_{S.1}(d) := \frac{f_1^2}{d}$$

$$(3) \phi_{P.1}(d) := \text{atan}\left[\frac{D_1}{L_{P.1}(d)}\right]$$

$$(4) \phi_{S.1}(d) := \text{atan}\left[\frac{D_1}{L_{S.1}(d)}\right]$$

$$(5) M := \frac{\cos\left[\text{asin}\left[\frac{\lambda}{d_h} - \sin[\theta_{P.I.1}]\right]\right]}{\cos[\theta_{P.I.1}]}$$

$$M = 3.003626$$

$$(6) D_2 := M D_1$$

$$D_2 = 3.003626$$

$$(7) \theta_{P.I.2}(d) := \theta_{P.I.1} - \phi_{P.1}(d)$$

---

F I G. 30C1



$$(8) \theta_{P.d.1} := \text{asin} \left[ \frac{\lambda}{d_h} - \sin [\theta_{P.l.1}] \right] \quad \theta_{P.d.1} = 32 \text{ deg}$$

$$(9) \theta_{P.d.2}(d) := \text{asin} \left[ \frac{\lambda}{d_h} - \sin [\theta_{P.l.2}(d)] \right]$$

$$(10) \phi_{P.2}(d) := \theta_{P.d.2}(d) - \theta_{P.d.1}$$

$$(11) L_{P.2}(d) := \frac{D_2}{\tan [\phi_{P.2}(d)]}$$

$$(12) L_{S.2}(d) := L_{S.1}(d)$$

FIG. 30C2

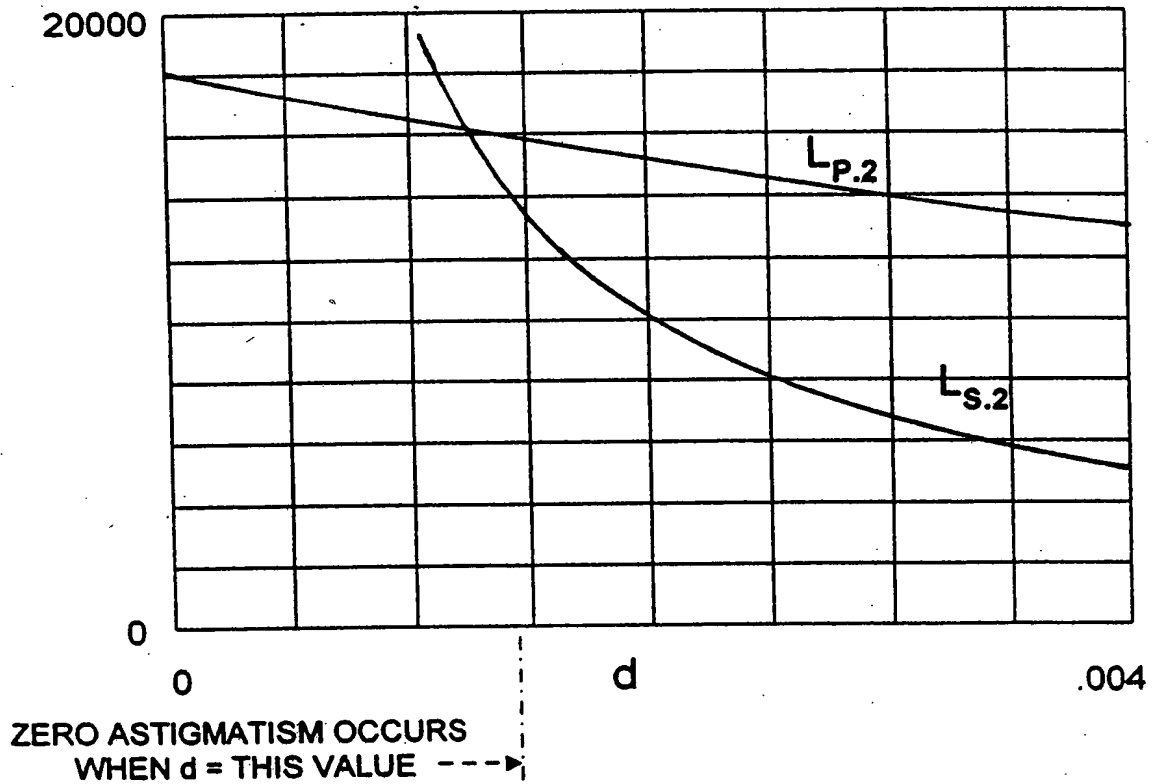


**S AND P IMAGE DISTANCES IN THE IMAGE PLANE OF THE FOCUSING LENS AS A FUNCTION OF THE DISTANCE FROM THE FOCAL POINT OF THE COLLIMATING LENS TO THE S SOURCE. HOE PLACED AFTER THE COLLIMATING LENS.  $\theta_{P.i.1}$  IS THE ANGLE OF INCIDENCE OF THE LOWER PORTION OF THE P-BEAM ON THE SURFACE OF THE HOE.  $\delta$  IS THE VLD ASTIGMATIC DIFFERENCE.**

**S AND P IMAGE LOCATIONS - COLLIMATING LENS AND HOE ONLY**

$$\lambda = 0.00067 \text{ mm} \quad f_1 = 4.5 \text{ mm} \quad \theta_{P.i.1} = 73.6 \text{ deg} \quad \delta = 0.01 \text{ mm}$$

$$L_{P.2}(d), L_{S.2}(d)$$



$$d := .001248 \text{ mm}$$

$$L_{P.2}(d) = 1.622582 \cdot 10^4 \text{ mm} \quad L_{S.2}(d) = 1.622596 \cdot 10^4 \text{ mm}$$

**FIG. 30D**

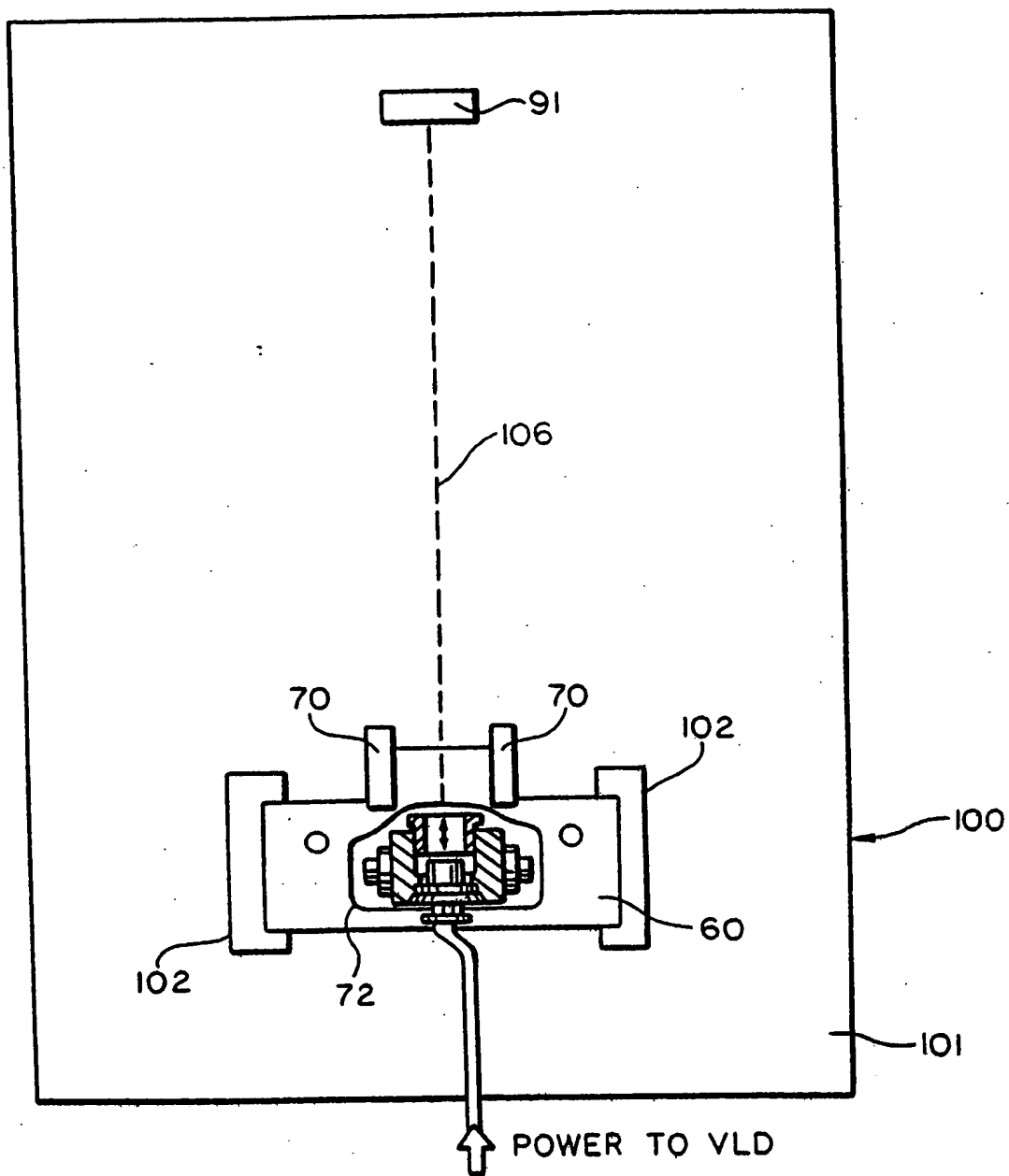


FIG. 31A1



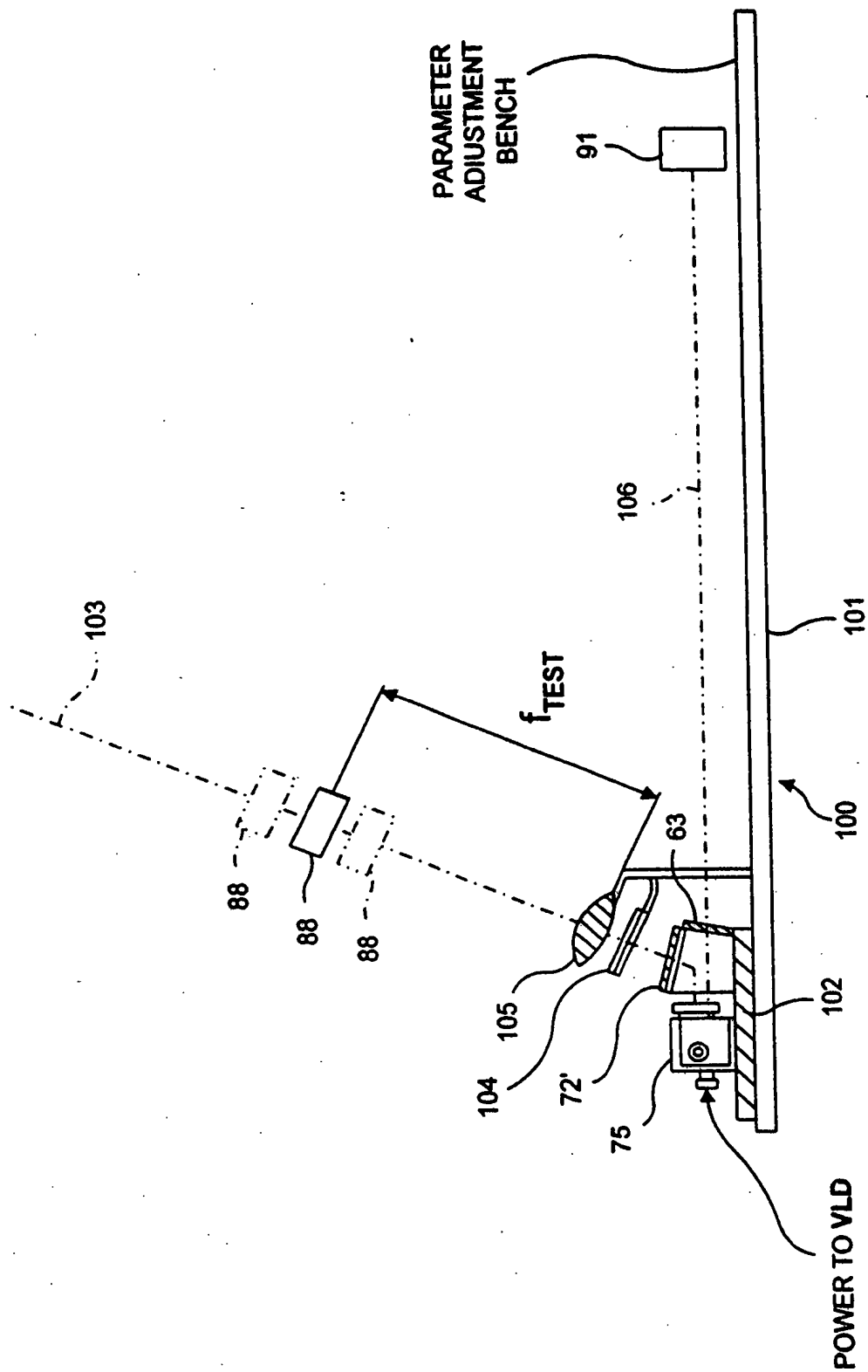


FIG. 31A2

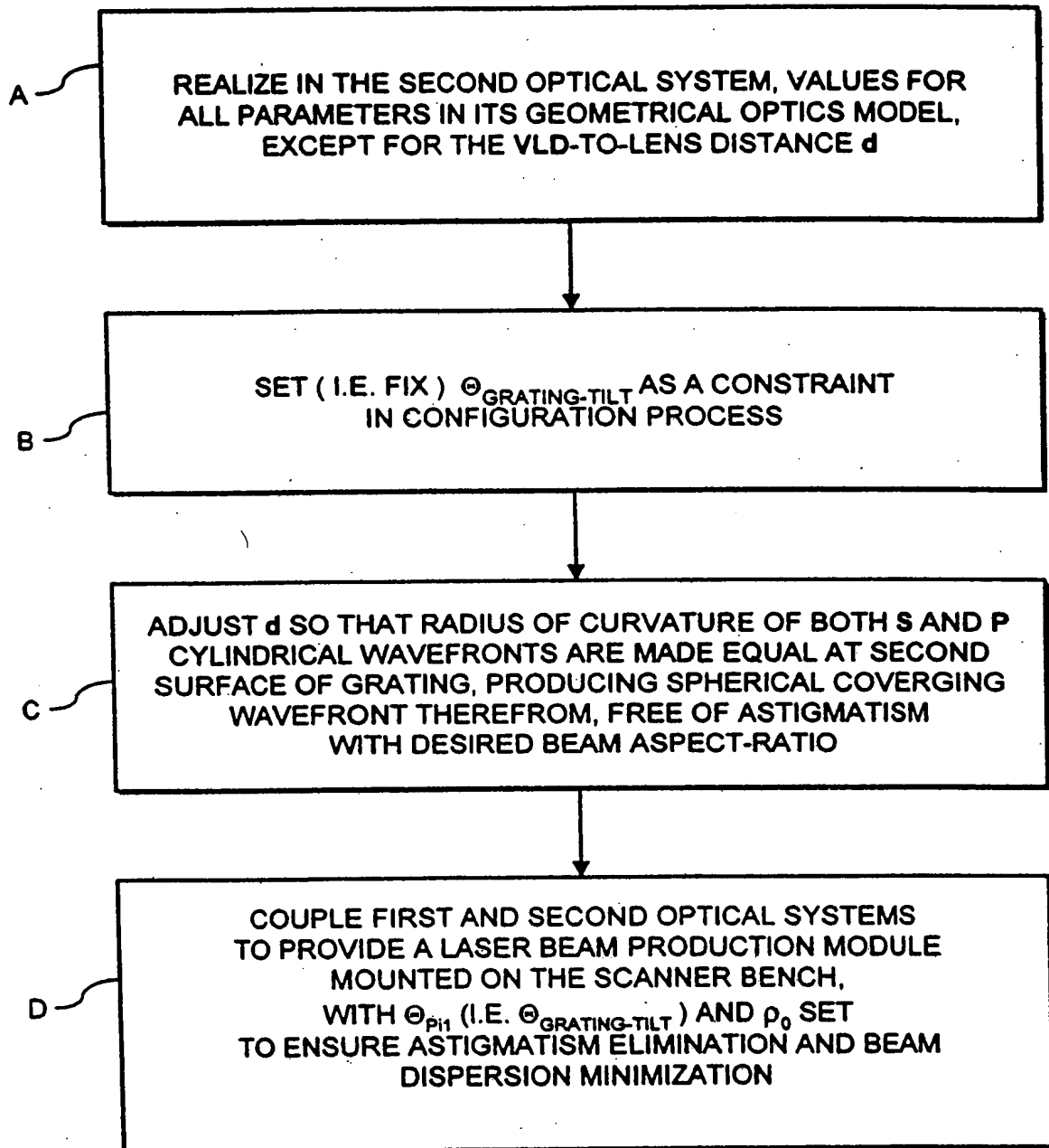


FIG. 31B

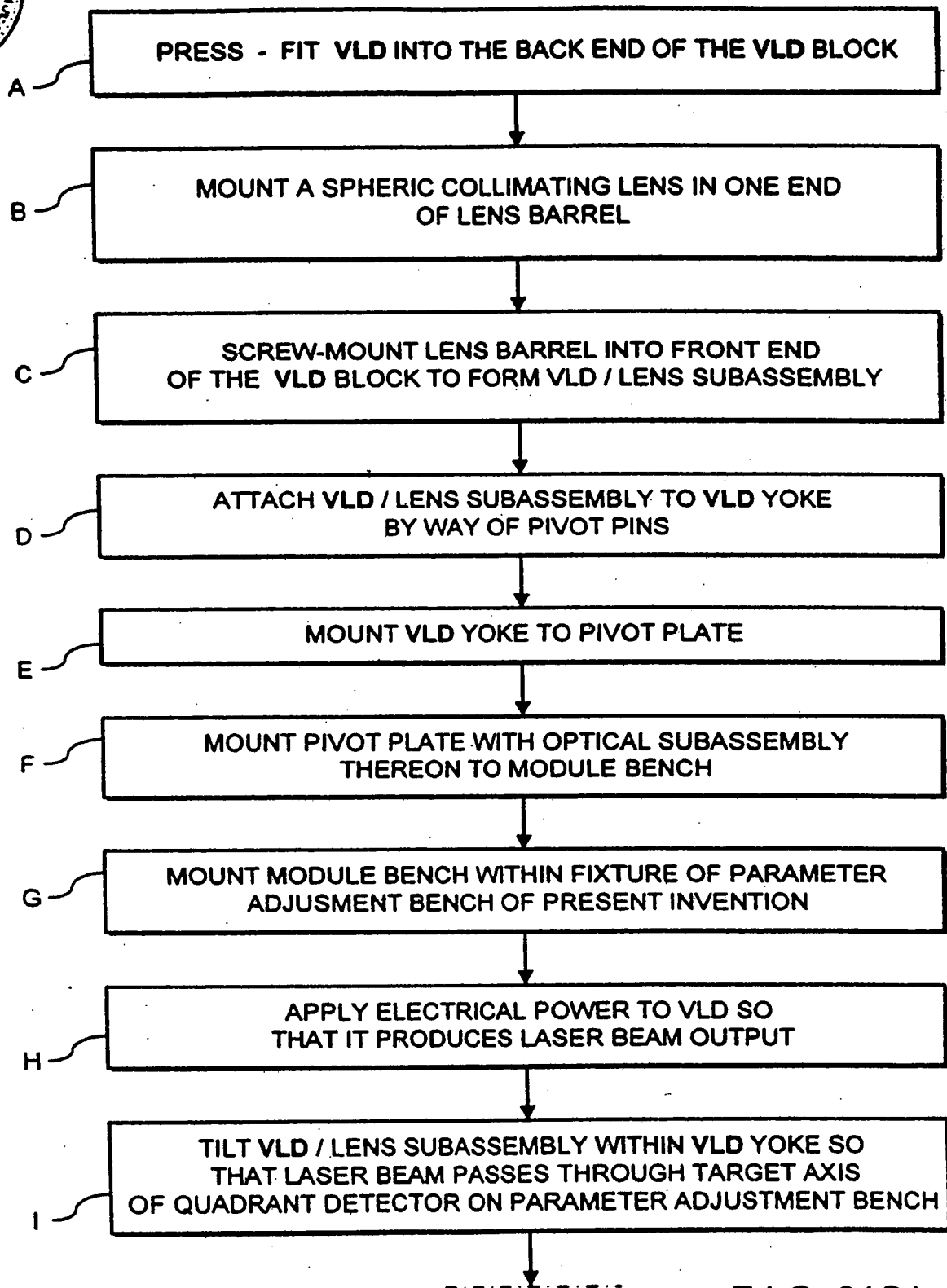


FIG. 31C1

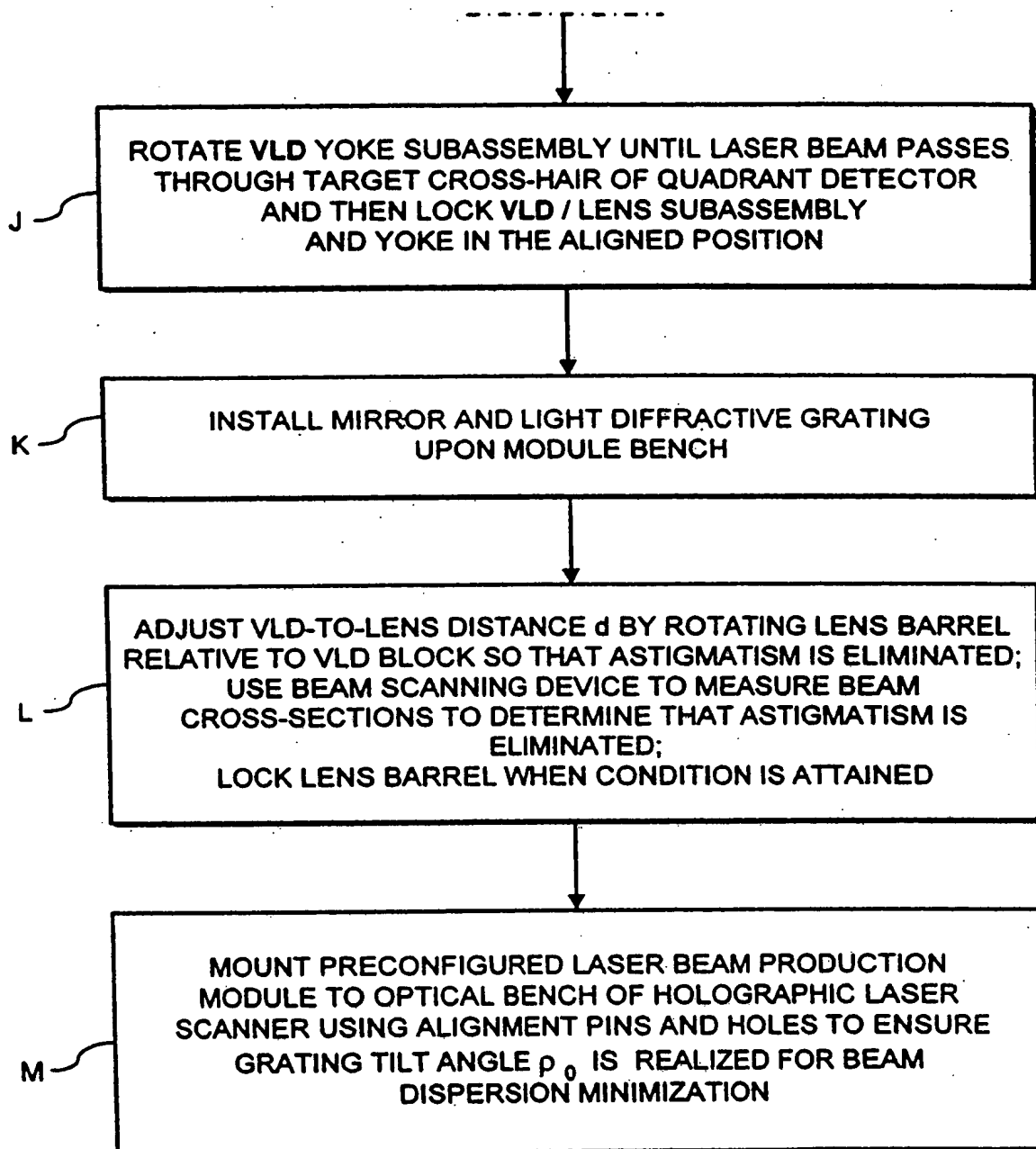
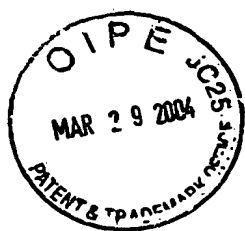


FIG. 31C2

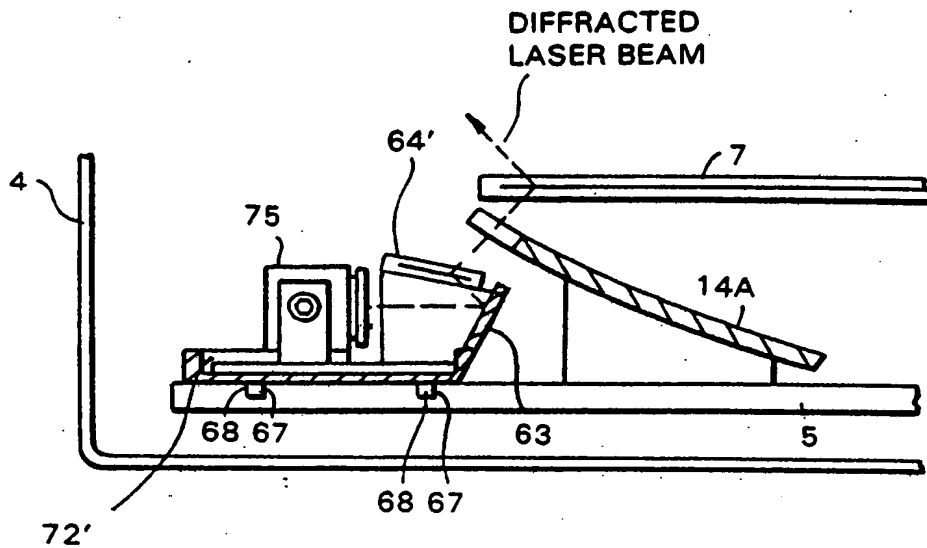


FIG. 31D

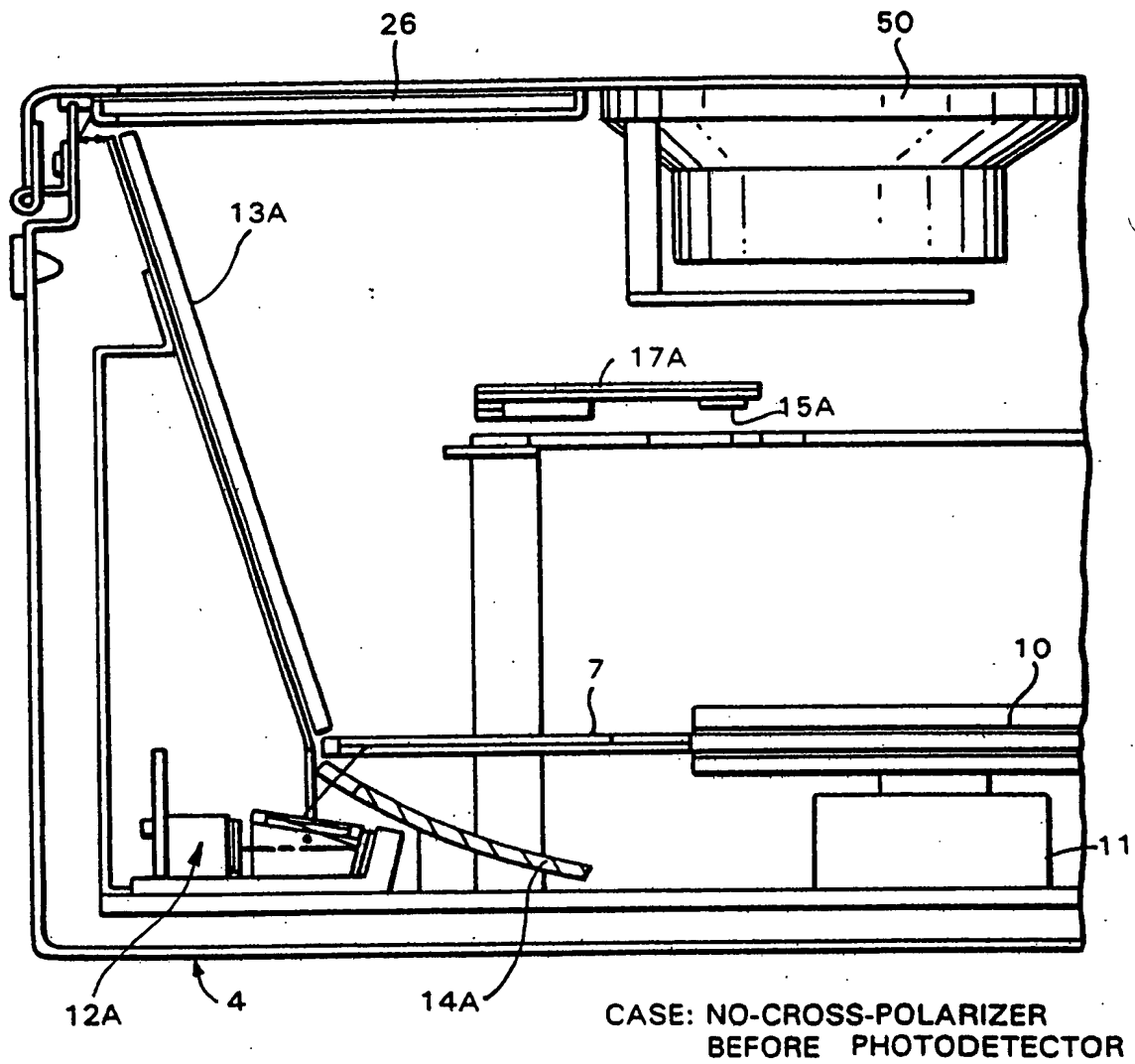
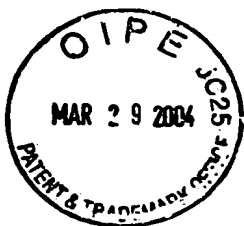


FIG. 32



A

CREATE 3-D GEOMETRICAL MODEL OF HOLOGRAPHIC LASER SCANNER BASED ON PARAMETERS OBTAINED FROM PRIOR STAGES OF SCANNER DESIGN METHOD, EXCLUDING PARABOLIC LIGHT COLLECTION MIRRORS AND PHOTODETECTORS

B

PERFORM BRAGG SENSITIVITY ANALYSIS ON EACH HOLOGRAPHIC FACET USING THE HSD WORKSTATION TO DETERMINE THE RANGE OF INCIDENCE ANGLES OFF BRAGG, AT WHICH LIGHT RAYS REFLECTED OFF THE PARABOLIC MIRROR CAN?WILL BE TRANSMITTED THROUGH THE FACETS WITH MINIMUM DIFFRACTION (I.E. MAXIMUM TRANSMISSION) TOWARDS THE PHOTODETECTOR DURING LIGHT COLLECTION OPERATIONS

C

USE THE HSD WORKSTATION TO TRACE ALL INCOMING LIGHT RAYS REFLECTED OFF A BAR CODE SYMBOL ANYWHERE IN THE SPECIFIED SCANNING VOLUME ONTO THE FACETS OF THE PREDESIGNED SCANNING DISC, AND BASED ON THIS ANALYSIS, IDENTIFY A POINT(S) ABOVE THE SCANNING DISC AND BELOW TOP EDGE OF ASSOCIATED BEAM FOLDING MIRROR, WHICH IS FREE OF INCOMING LIGHT RAYS

D

LOCATE THE POSITION ( I.E. CENTER AND OPTICAL AXIS ORIENTATION ) OF THE PHOTODETECTORS USING THE "RAY FREE POINT" INFORMATION ACQUIRED DURING BLOCK C ABOVE

FIG. 33A

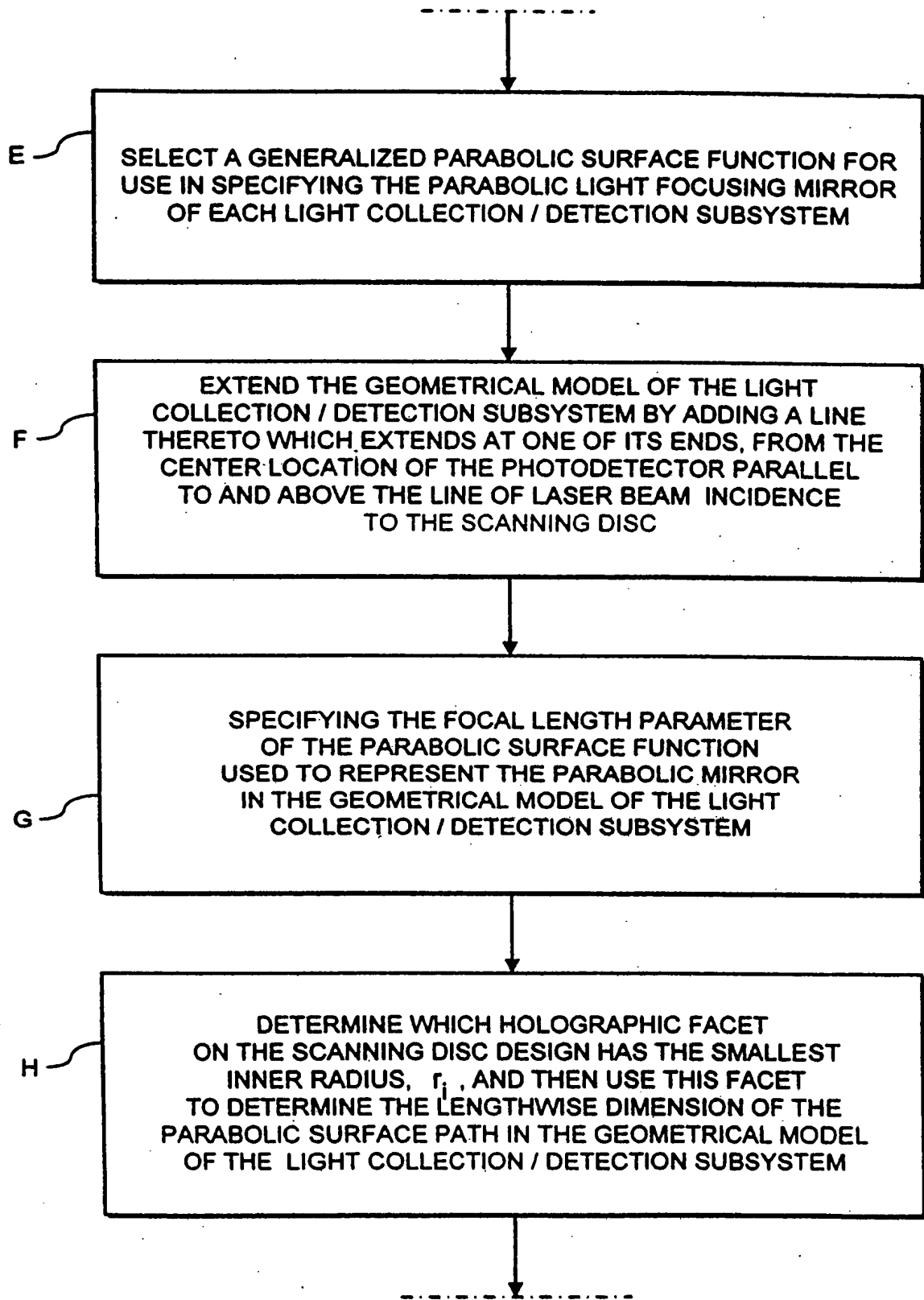


FIG. 33B



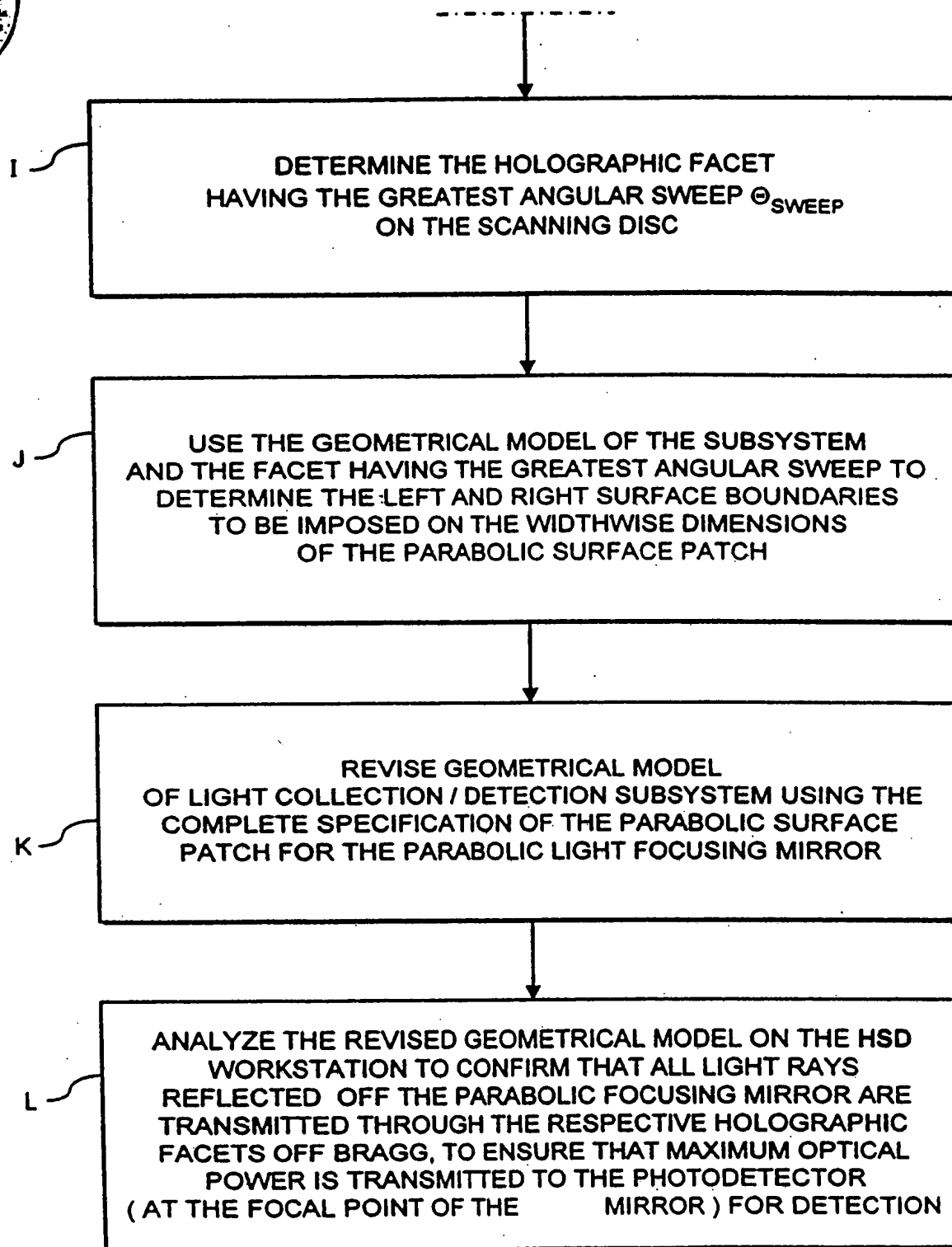


FIG. 33C

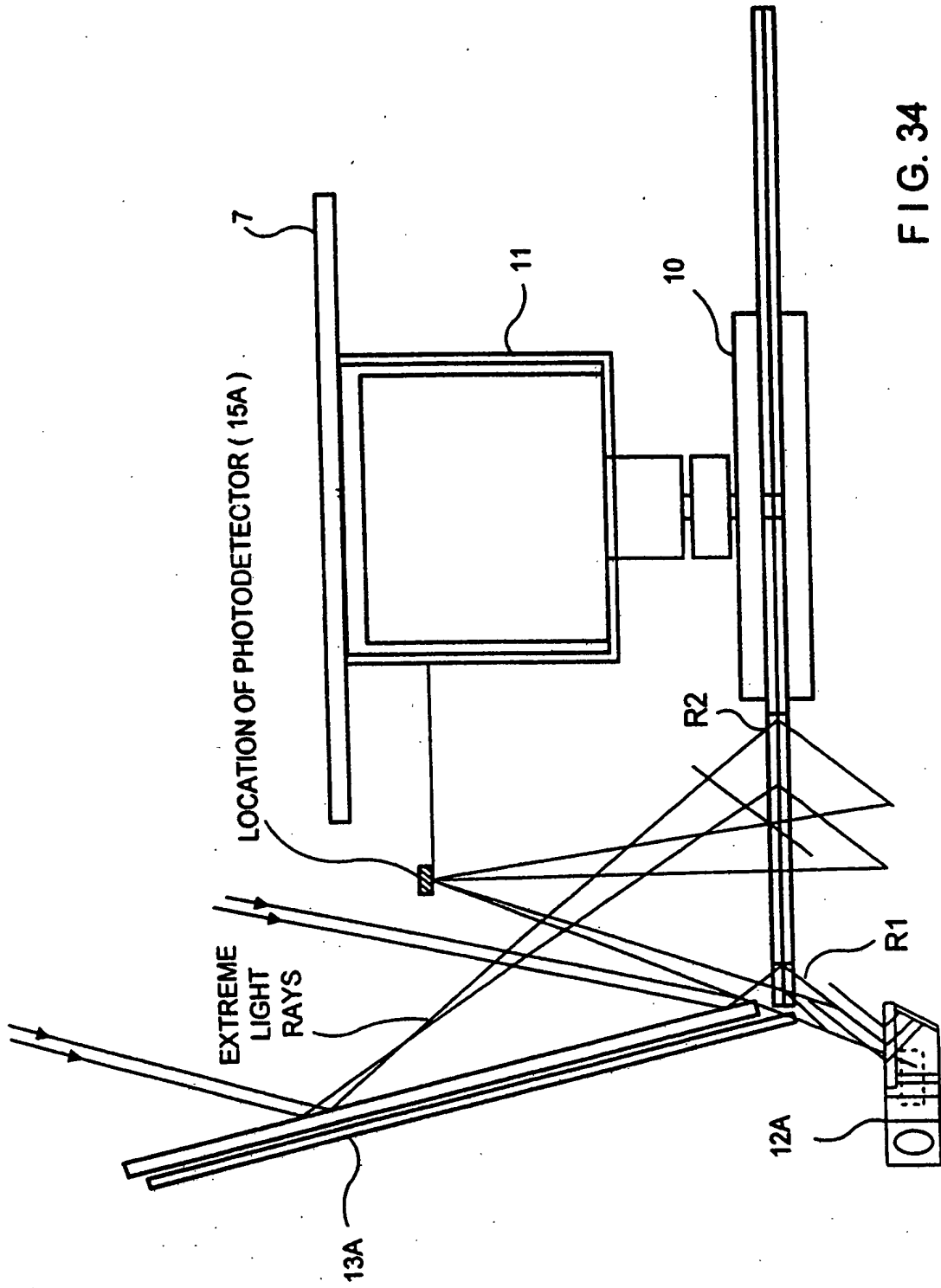
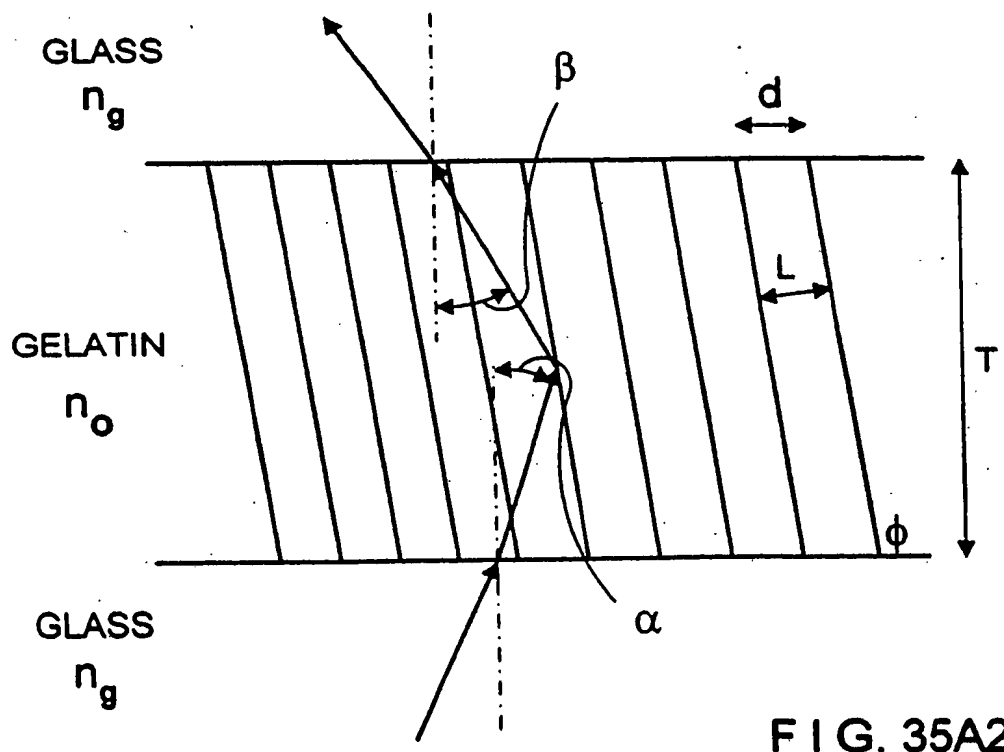
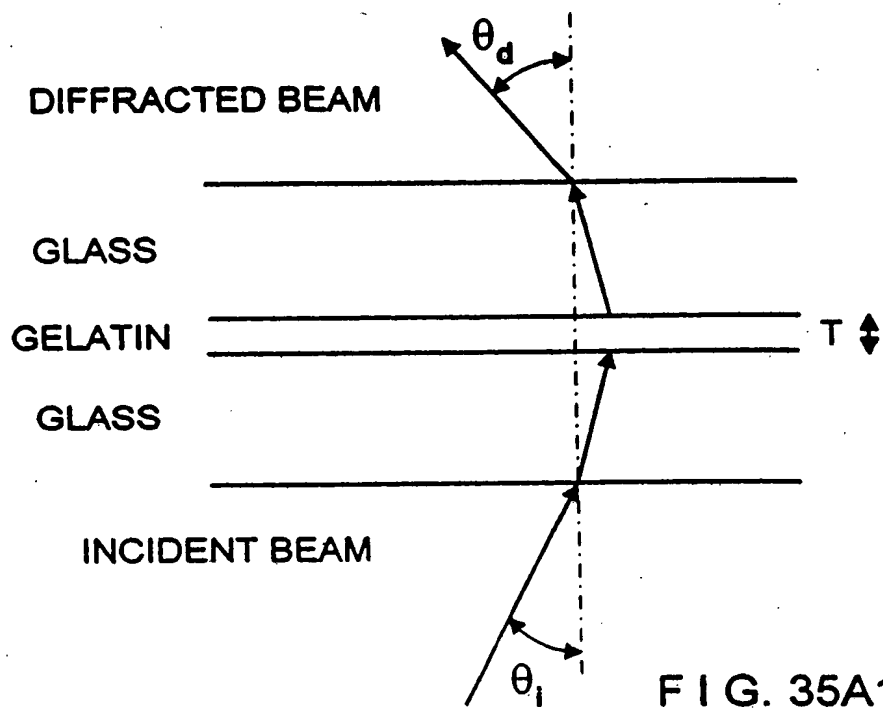


FIG. 34





**S AND P POLARIZATION DIFFRACTION EFFICIENCY FOR THE TECH20  
HOLOGRAPHIC SCANNING DISC AS FUNCTIONS OF THE EXTERNAL ANGLE  
OF INCIDENCE.**

**S AND P DIFFRACTION EFFICIENCY AS A FUNCTION OF THE DEVIATION FROM  
THE BRAGG ANGLE . SLANTED FRINGES ARE INCLUDED. IN THIS FILE, WE ARE  
CONSIDERING THE EXTERNAL ANGLES. THE EXTERNAL ANGLES ARE RELATED  
TO THE INTERNAL ANGLES VIA SNELL'S LAW. THE INTERNAL ANGLES ARE  $\theta.0$ ,**

**$\alpha$ , AND  $\beta$  , WHERE  $2\theta.0 = (\alpha + \beta)$  . .**

**$\alpha$  = THE ANGLE OF REFRACTION,  $\beta$  - THE INTERNAL ANGLE OF DIFFRACTION,  
AND  $\theta.0$  IS THE ANGLE BETWEEN THE REFRACTED BEAM AND THE BRAGG  
PLANES. THE EXTERNAL ANGLES ARE  $\theta.i$  ( THE ANGLE OF INCIDENCE ) AND  
 $\theta.d$  (THE ANGLE OF DIFFRACTION).**

**DEFINITIONS:**

**$\theta_i$  = ANGLE OF INCIDENCE (EXTERNAL)**

**$\alpha$  = ANGLE OF INCIDENCE (INTERNAL)**

**$\beta$  = ANGLE OF DIFFRACTION (INTERNAL)**

**$\delta$  = DEVIATION FROM THE BRAGG ANGLE (INTERNAL)**

**$\delta.0$  = DEVIATION FROM THE BRAGG ANGLE (EXTERNAL)**

**$\phi$  = TILT OF BRAGG PLANES**

**=  $\pi/2$  FOR NO TILT**

**L = SEPARATION OF THE BRAGG PLANES**

**T = THICKNESS OF HOE MEDIUM**

**d = EXTERNAL FRINGE SPACING**

**$n_0$  = AVERAGE REFRACTIVE INDEX OF THE HOE MEDIUM**

**$n_1$  =  $\Delta n$  OF HOE FRINGE STRUCTURE**

**$\lambda_a$  = WAVELENGTH IN AIR**

**$\delta\lambda$  = DEVIATION FROM  $\lambda_a$  ( BRAGG  $\lambda$  )**

**F I G. 35B**



FIXED, OR ESTABLISHED PARAMETERS:

$n_0, n_1, \theta_i, \theta_d, \delta, \delta\lambda, \lambda_a, T.$

$$n_0 := 1.4$$

$$\text{deg} = \frac{\pi}{180}$$

$$n_1 := 0.146$$

$$\theta_i := 43 \text{ deg}$$

$$\theta_d := 27.2 \text{ deg}$$

$$\delta_e := 0 \text{ deg}, .2 \text{ deg}, \dots, .70 \text{ deg}$$

$$\delta_\lambda := 0$$

$$T := 2.2$$

$$\lambda_a := .670$$

FIG. 35B1



$$(1) \alpha := \text{asin} \left[ \frac{\sin [\theta_i]}{n_0} \right]$$

$$(2) \beta := \text{asin} \left[ \frac{\sin [\theta_d]}{n_0} \right]$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta - \alpha}{2}$$

$$(4) d := \frac{\lambda_a}{[n_0(\sin(\alpha) + \sin(\beta))]}$$

GRATING  
EQUATION

$$(5) L := d \sin(\phi)$$

$$(6) C_R := \cos(\alpha)$$

$$(7) C_S := \cos(\alpha) - \frac{\lambda_a}{n_0 L} \cos(\phi)$$

$$(8) N := \pi n_1 \frac{T}{\lambda_a \sqrt{C_R C_S}}$$

$$(9) \delta[\delta_e] := \left[ \text{asin} \left[ \frac{\sin[\theta_i + \delta_e]}{n_0} \right] - \alpha \right]$$

$$(10) \Gamma[\delta_e] := 2\pi \delta[\delta_e] \frac{\sin(\phi - \alpha)}{L} - \delta_\lambda \frac{\pi}{n_0 L^2}$$

$$(11) S[\delta_e] := \Gamma[\delta_e] \frac{T}{2 C_S}$$

FIG. 35C1



DIFFRACTION EFFICIENCIES:  $E_s$  AND  $E_p$  AS A FUNCTION OF  $\delta_e$

$$(12) \quad E_s[\delta_e] := \frac{\left[ \sin \left[ \sqrt{N^2 + S[\delta_e]^2} \right] \right]^2}{1 + \frac{S[\delta_e]^2}{N^2}}$$

$$(13) \quad E_p[\delta_e] := \frac{\left[ \sin \left[ \sqrt{(N \cos(2(\alpha - \phi)))^2 + S[\delta_e]^2} \right] \right]^2}{1 + \frac{S[\delta_e]^2}{(N \cos(2(\alpha - \phi)))^2}}$$

$$(14) \quad E_{av}[\delta_e] := \frac{E_s[\delta_e] + E_p[\delta_e]}{2}$$

FIG. 35C2



RELATIVE DIFFRACTION EFFICIENCY FOR UNPOLARIZED LIGHT AS  
A FUNCTION OF DEVIATION FROM THE BRAGG ANGLE - FACET 1

$$\lambda_a = .67 \quad n_0 = 1.4 \quad n_1 = 0.146 \quad \theta_i = 43 \text{ deg}$$

$$\theta_d = 27.2 \text{ deg} \quad T = 2.2$$

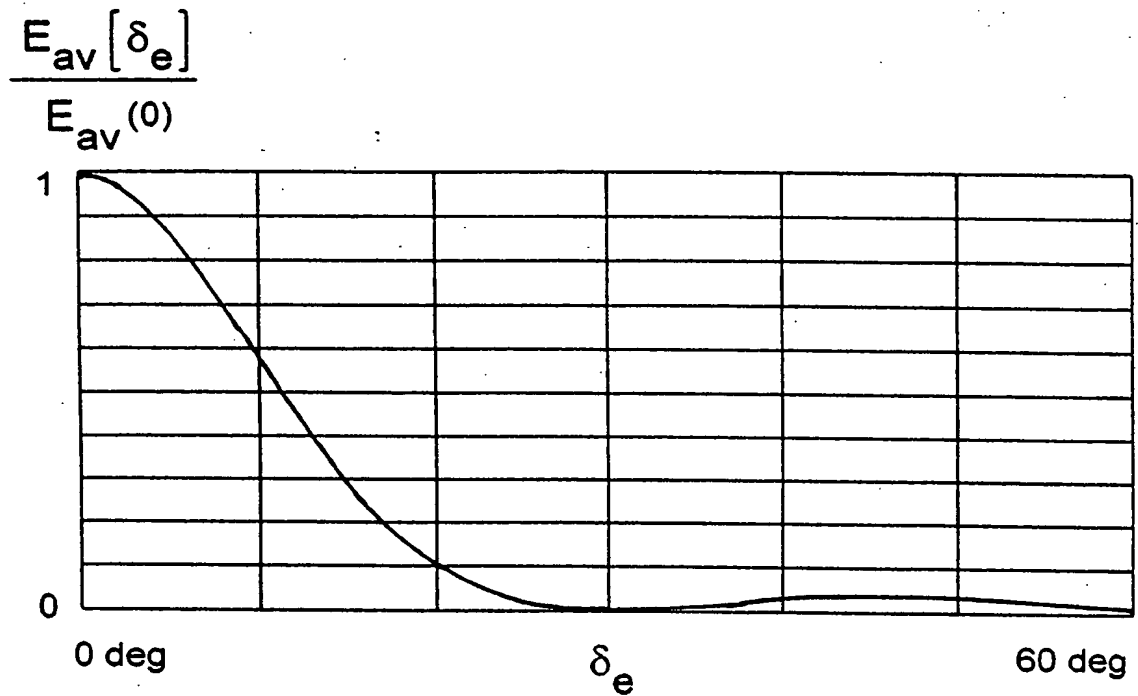


FIG. 35D1





RELATIVE DIFFRACTION EFFICIENCY FOR UNPOLARIZED LIGHT AS  
A FUNCTION OF DEVIATION FROM THE BRAGG ANGLE - FACET 16

$$\lambda_a = .670 \quad n_0 = 1.4 \quad n_1 = 0.145 \quad \theta_i = 43 \text{ deg}$$

$$\theta_d = 41.8 \text{ deg} \quad T = 2.2$$

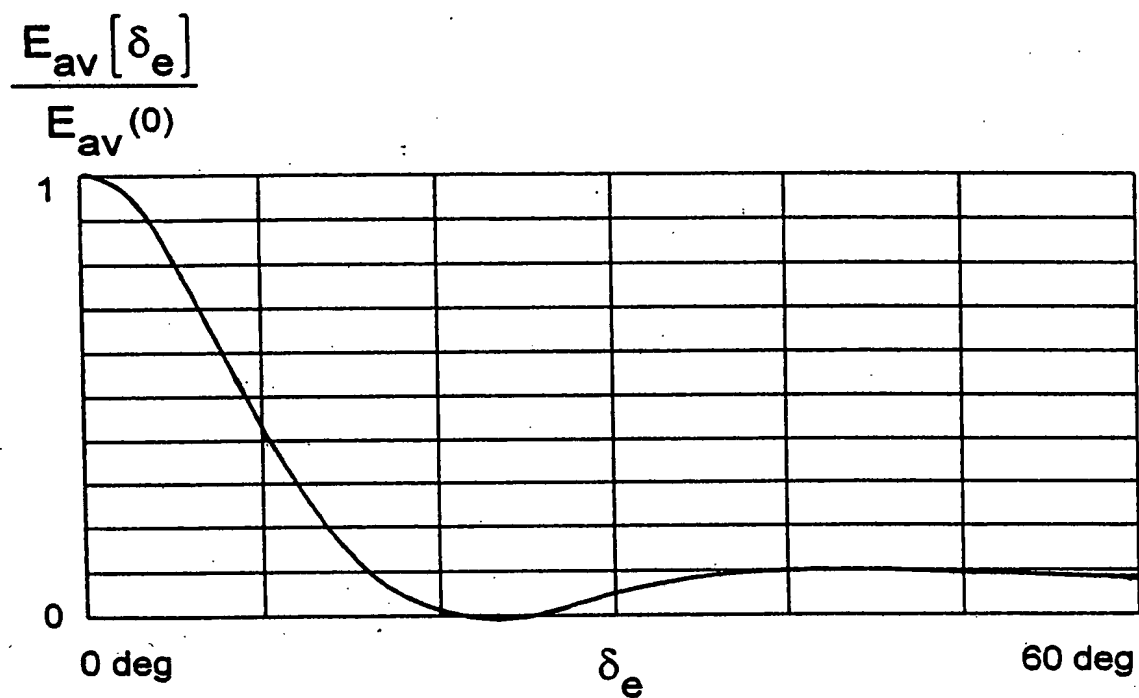
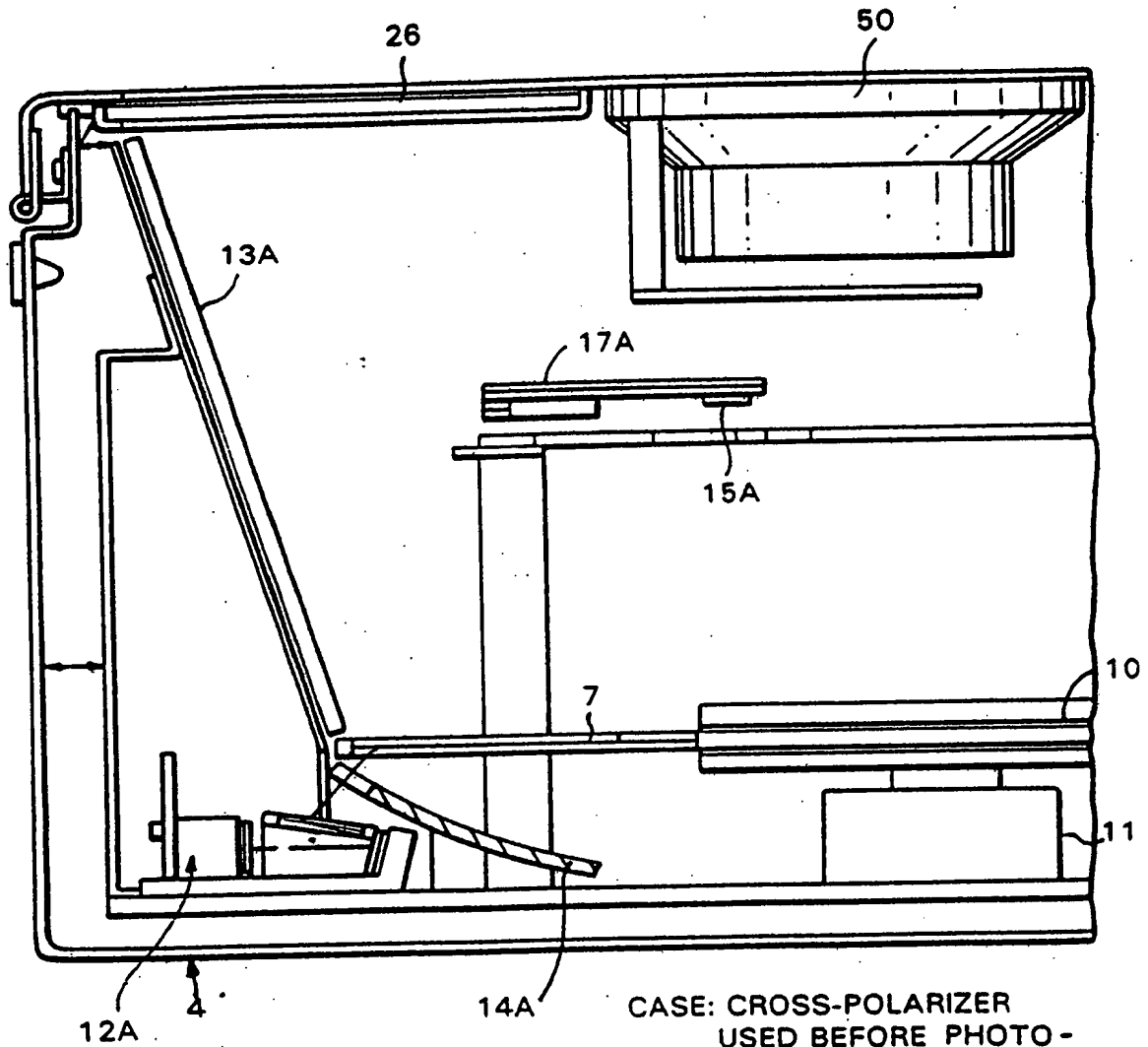
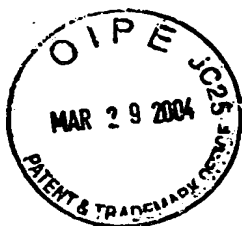


FIG. 35D2



CASE: CROSS-POLARIZER  
USED BEFORE PHOTO-  
DETECTOR

FIG. 36



**S POLARIZATION DIFFRACTION EFFICIENCY FOR THE TECH20 HOLOGRAPHIC SCANNING DISC AS A FUNCTION OF THE EXTERNAL ANGLE OF INCIDENCE. THIS IS THE SECOND CASE OF INTEREST WHEN A CROSSED POLARIZER IS USED ON THE DETECTOR.**

**S DIFFRACTION EFFICIENCY AS A FUNCTION OF THE DEVIATION FROM THE BRAGG ANGLE. SLANTED FRINGES ARE INCLUDED. IN THIS FILE, WE ARE CONSIDERING THE EXTERNAL ANGLES. THE EXTERNAL ANGLES ARE RELATED TO THE INTERNAL ANGLES VIA SNELL'S LAW. THE INTERNAL ANGLES ARE  $\theta_0$ ,**

**$\alpha$ , AND  $\beta$ , WHERE  $2\theta_0 = (\alpha + \beta)$ .**

**$\alpha$  = THE ANGLE OF REFRACTION,  $\beta$  - THE INTERNAL ANGLE OF DIFFRACTION, AND  $\theta_0$  IS THE ANGLE BETWEEN THE REFRACTED BEAM AND THE BRAGG PLANES. THE EXTERNAL ANGLES ARE  $\theta_i$  ( THE ANGLE OF INCIDENCE ) AND  $\theta_d$  (THE ANGLE OF DIFFRACTION).**

**DEFINITIONS:**

**$\theta_i$  = ANGLE OF INCIDENCE (EXTERNAL)**

**$\alpha$  = ANGLE OF INCIDENCE (INTERNAL)**

**$\beta$  = ANGLE OF DIFFRACTION (INTERNAL)**

**$\delta$  = DEVIATION FROM THE BRAGG ANGLE (INTERNAL)**

**$\delta_0$  = DEVIATION FROM THE BRAGG ANGLE (EXTERNAL)**

**$\phi$  = TILT OF BRAGG PLANES**

**=  $\pi/2$  FOR NO TILT**

**L = SEPARATION OF THE BRAGG PLANES**

**T = THICKNESS OF HOE MEDIUM**

**d = EXTERNAL FRINGE SPACING**

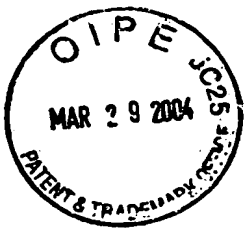
**$n_0$  = AVERAGE REFRACTIVE INDEX OF THE HOE MEDIUM**

**$n_1$  =  $\Delta n$  OF HOE FRINGE STRUCTURE**

**$\lambda_a$  = WAVELENGTH IN AIR**

**$\delta\lambda$  = DEVIATION FROM  $\lambda_a$  ( BRAGG  $\lambda$  )**

**FIG. 37A**



FIXED, OR ESTABLISHED PARAMETERS:

$n_0, n_1, \theta_i, \theta_d, \delta, \delta\lambda, \lambda_a, T.$

$$n_0 := 1.4$$

$$\text{deg} = \frac{\pi}{180}$$

$$n_1 := 0.146$$

$$\theta_i := 43 \text{ deg}$$

$$\theta_d := 27.2 \text{ deg}$$

$$\delta_e := 0 \text{ deg}, .2 \text{ deg}, \dots, .70 \text{ deg}$$

$$\delta_\lambda := 0$$

$$T := 2.2$$

$$\lambda_a := .670$$

FIG. 37A1



$$(1) \alpha := a \sin \left[ \frac{\sin [\theta_i]}{n_0} \right]$$

$$(2) \beta := a \sin \left[ \frac{\sin [\theta_d]}{n_0} \right]$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta - \alpha}{2}$$

$$(4) d := \frac{\lambda_a}{[n_0(\sin(\alpha) + \sin(\beta))]} \quad \text{GRATING EQUATION}$$

$$(5) L := d \sin(\phi) \quad (6) C_R := \cos(\alpha)$$

$$(7) C_s := \cos(\alpha) - \frac{\lambda_a}{n_0 L} \cos(\phi)$$

$$(8) N := \pi n_1 \frac{T}{\lambda_a \sqrt{C_R C_s}}$$

$$(9) \delta[\delta_e] := \left[ a \sin \left[ \frac{\sin[\theta_i + \delta_e]}{n_0} \right] - \alpha \right]$$

$$(10) \Gamma[\delta_e] := 2\pi \delta[\delta_e] \frac{\sin(\phi - \alpha)}{L} - \delta_\lambda \frac{\pi}{n_0 L^2}$$

$$(11) S[\delta_e] := \Gamma[\delta_e] \frac{T}{2 C_s}$$

S-POLARIZATION DIFFRACTION EFFICIENCY:  $E_s$  AS A FUNCTION OF  $\delta_e$

$$(12) E_s[\delta_e] := \frac{\left[ \sin \left[ \sqrt{N^2 + S[\delta_e]^2} \right] \right]^2}{1 + \frac{S[\delta_e]^2}{N^2}}$$

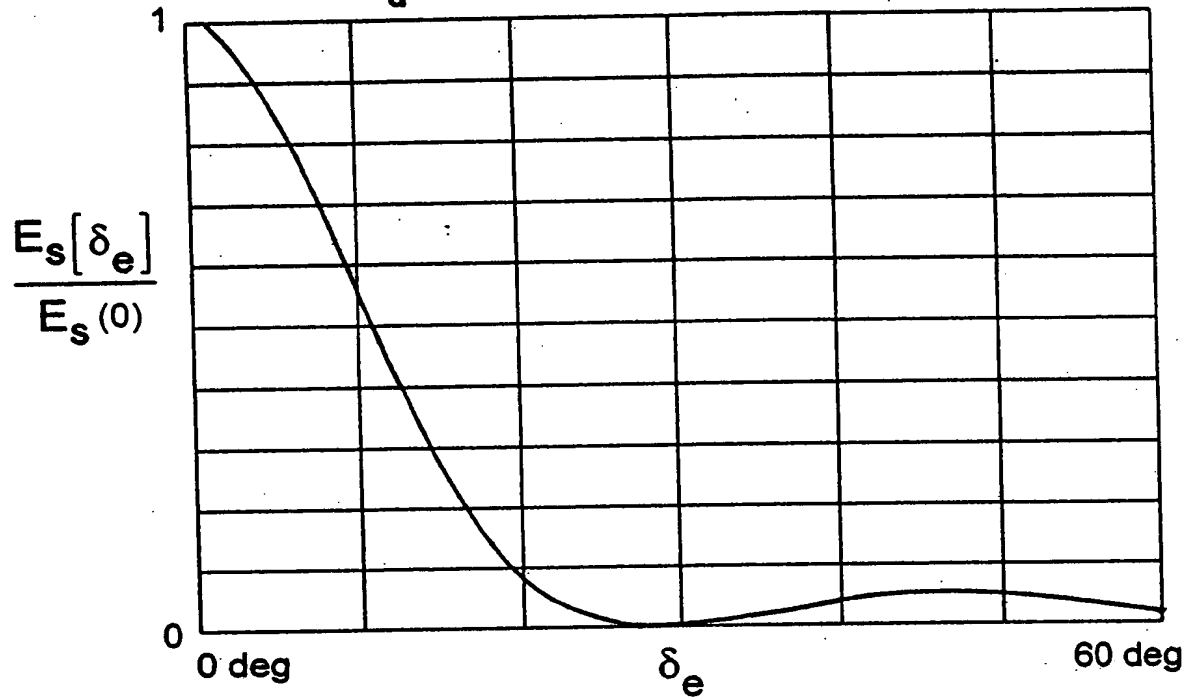
FIG. 37B



**RELATIVE DIFFRACTION EFFICIENCY FOR S-POLARIZED LIGHT AS  
A FUNCTION OF DEVIATION FROM THE BRAGG ANGLE - FACET 1**

$$\lambda_a = .67 \quad n_0 = 1.4 \quad n_1 = 0.146 \quad \theta_i = 43 \text{ deg}$$

$$\theta_d = 27.2 \text{ deg} \quad T = 2.2$$



$$\text{PerCentLoss} := 100 \left[ \frac{1}{28 \text{ deg}} \right] \left[ \int_{25 \text{ deg}}^{53 \text{ deg}} \frac{E_s[\delta_e]}{E_s(0)} d\delta_e \right]$$

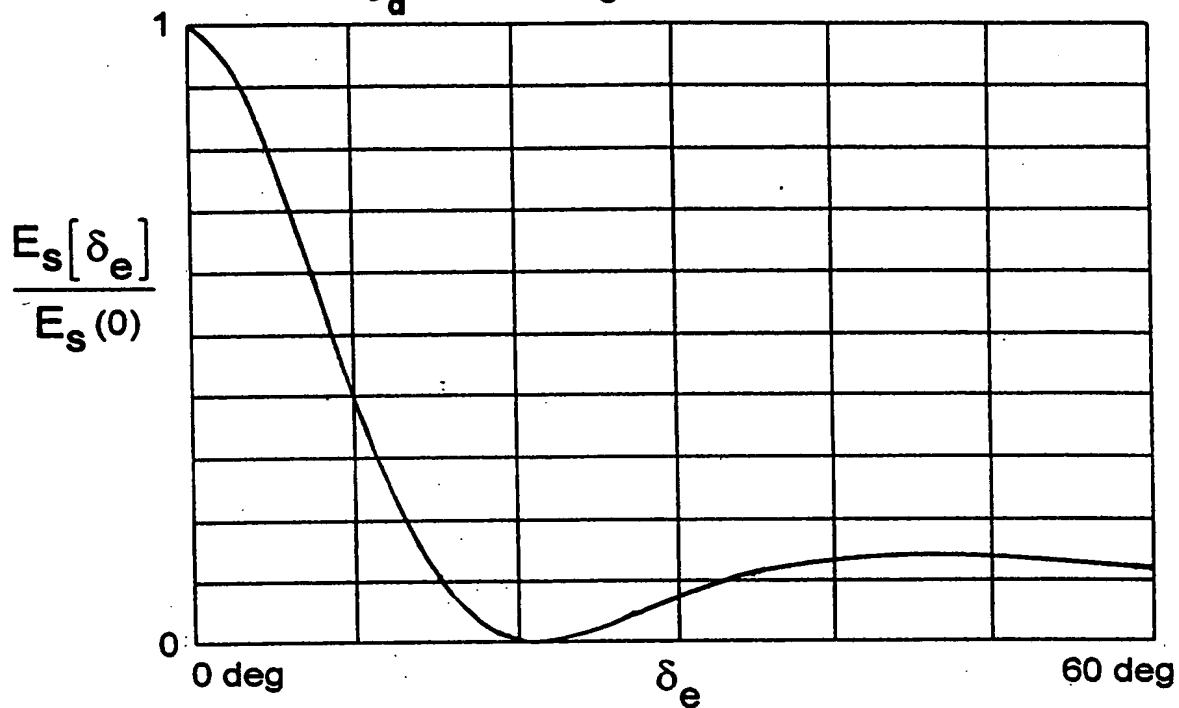
$$\text{PerCentLoss} := 3$$

**FIG. 37C1**



$$\lambda_a = .670 \quad n_0 = 1.4 \quad n_1 = 0.145 \quad \theta_i = 43 \text{ deg}$$

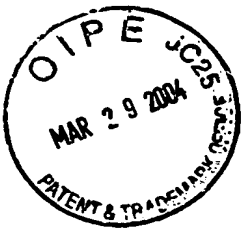
$$\theta_d = 41.8 \text{ deg} \quad T = 2.2$$



$$\text{PerCentLoss} := 100 \left[ \frac{1}{28 \text{ deg}} \right] \left[ \int_{25 \text{ deg}}^{53 \text{ deg}} \frac{E_s[\delta_e]}{E_s(0)} d\delta_e \right]$$

$$\text{PerCentLoss} := 10.972$$

FIG. 37C2



**P POLARIZATION DIFFRACTION EFFICIENCY FOR THE TECH20  
HOLOGRAPHIC SCANNING DISC AS A FUNCTION OF THE EXTERNAL ANGLE  
OF INCIDENCE. THIS IS THE CASE OF INTEREST WHEN A CROSSED  
POLARIZER IS USED ON THE DETECTOR.**

**P DIFFRACTION EFFICIENCY AS A FUNCTION OF THE DEVIATION FROM THE  
BRAGG ANGLE . SLANTED FRINGES ARE INCLUDED. IN THIS FILE, WE ARE  
CONSIDERING THE EXTERNAL ANGLES. THE EXTERNAL ANGLES ARE RELATED  
TO THE INTERNAL ANGLES VIA SNELL'S LAW. THE INTERNAL ANGLES ARE  $\theta_0$ ,**

**$\alpha$ , AND  $\beta$  , WHERE  $2\theta_0 = (\alpha + \beta)$  .**

**$\alpha$  = THE ANGLE OF REFRACTION,  $\beta$  - THE INTERNAL ANGLE OF DIFFRACTION,  
AND  $\theta_0$  IS THE ANGLE BETWEEN THE REFRACTED BEAM AND THE BRAGG  
PLANES. THE EXTERNAL ANGLES ARE  $\theta_i$  ( THE ANGLE OF INCIDENCE ) AND  
 $\theta_d$  (THE ANGLE OF DIFFRACTION).**

**DEFINITIONS:**

**$\theta_i$  = ANGLE OF INCIDENCE (EXTERNAL)**

**$\alpha$  = ANGLE OF INCIDENCE (INTERNAL)**

**$\beta$  = ANGLE OF DIFFRACTION (INTERNAL)**

**$\delta$  = DEVIATION FROM THE BRAGG ANGLE (INTERNAL)**

**$\delta_0$  = DEVIATION FROM THE BRAGG ANGLE (EXTERNAL)**

**$\phi$  = TILT OF BRAGG PLANES**

**=  $\pi/2$  FOR NO TILT**

**L = SEPARATION OF THE BRAGG PLANES**

**T = THICKNESS OF HOE MEDIUM**

**d = EXTERNAL FRINGE SPACING**

**$n_0$  = AVERAGE REFRACTIVE INDEX OF THE HOE MEDIUM**

**$n_1$  =  $\Delta n$  OF HOE FRINGE STRUCTURE**

**$\lambda_a$  = WAVELENGTH IN AIR**

**$\delta\lambda$  = DEVIATION FROM  $\lambda_a$  ( BRAGG  $\lambda$  )**

**FIG. 38A**





FIXED, OR ESTABLISHED

PARAMETERS:  $n_0$ ,  $\Delta n_1$ ,  $\theta_i$ ,  $\theta_d$ ,  $\delta$ ,  $\delta\lambda$ ,  $\lambda_a$ ,  $T$ .

$$n_0 := 1.4$$

$$\text{deg} = \frac{\pi}{180}$$

$$\Delta n_1 := 0.146$$

$$\theta_i := 43 \text{ deg}$$

$$\theta_d := 27.2 \text{ deg}$$

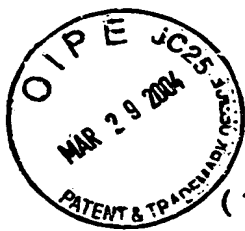
$$\delta := 0 \text{ deg}, .2 \text{ deg}, \dots, .70 \text{ deg}$$

$$\delta\lambda := 0$$

$$T := 2.2$$

$$\lambda_a := .670$$

FIG. 38A1



$$(1) \alpha := \text{asin} \left[ \frac{\sin [\theta_i]}{n_0} \right]$$

$$(2) \beta := \text{asin} \left[ \frac{\sin [\theta_d]}{n_0} \right]$$

$$(3) \phi := \frac{\pi}{2} - \frac{\beta - \alpha}{2}$$

$$(4) d := \frac{\lambda_a}{[n_0 (\sin(\alpha) + \sin(\beta))]}$$

GRATING  
EQUATION

$$(5) L := d \sin(\phi)$$

$$(6) C_R := \cos(\alpha)$$

$$(7) C_S := \cos(\alpha) - \frac{\lambda_a}{n_0 L} \cos(\phi)$$

$$(8) N := \pi n_1 \frac{T}{\lambda_a \sqrt{C_R C_S}}$$

$$(9) \delta[\delta_e] := \left[ \text{asin} \left[ \frac{\sin[\theta_i + \delta_e]}{n_0} \right] - \alpha \right]$$

$$(10) \Gamma[\delta_e] := 2\pi \delta[\delta_e] \frac{\sin(\phi - \alpha)}{L} - \delta_\lambda \frac{\pi}{n_0 L^2}$$

$$(11) S[\delta_e] := \Gamma[\delta_e] \frac{T}{2 C_S}$$

FIG. 38B1



**P-POLARIZATION DIFFRACTION EFFICIENCY:  
E<sub>p</sub> AS A FUNCTION OF δ<sub>e</sub>**

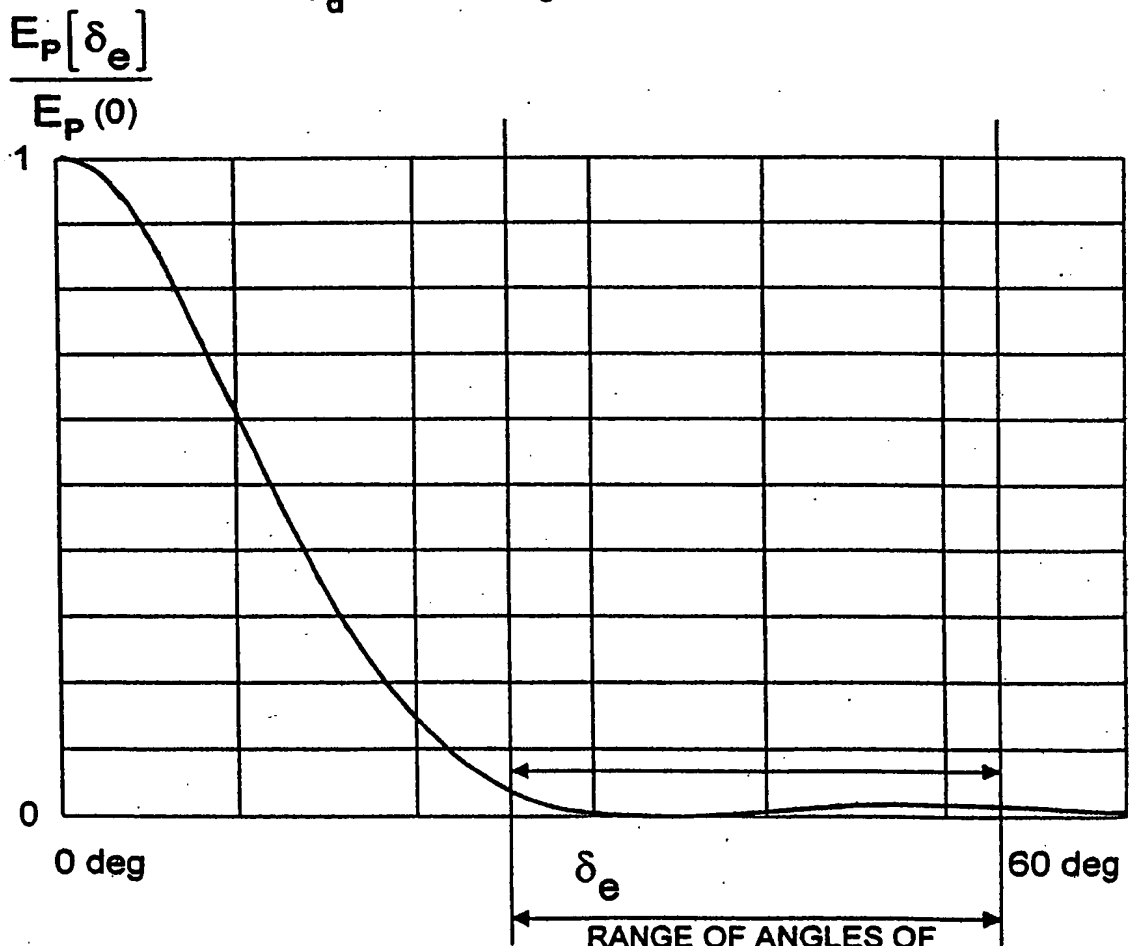
$$(12) E_p[\delta_e] := \frac{\left[ \sin \left[ \sqrt{(N \cos(2(\alpha - \phi)))^2 + S[\delta_e]^2} \right] \right]^2}{1 + \frac{S[\delta_e]^2}{(N \cos(2(\alpha - \phi)))^2}}$$

**FIG. 38B2**

**RELATIVE DIFFRACTION EFFICIENCY FOR P-POLARIZED LIGHT AS  
A FUNCTION OF DEVIATION FROM THE BRAGG ANGLE - FACET 1**

$$\lambda_a = .670 \quad n_0 = 1.4 \quad n_1 = 0.146 \quad \theta_i = 43 \text{ deg}$$

$$\theta_d = 27.2 \text{ deg} \quad T = 2.2$$



**FIG. 38C1**



RELATIVE DIFFRACTION EFFICIENCY FOR P-POLARIZED LIGHT AS  
A FUNCTION OF DEVIATION FROM THE BRAGG ANGLE - FACET 16

$$\lambda_a = .670 \quad n_0 = 1.4 \quad n_1 = 0.145 \quad \theta_i = 43 \text{ deg}$$
$$\theta_d = 41.8 \text{ deg} \quad T = 2.2$$

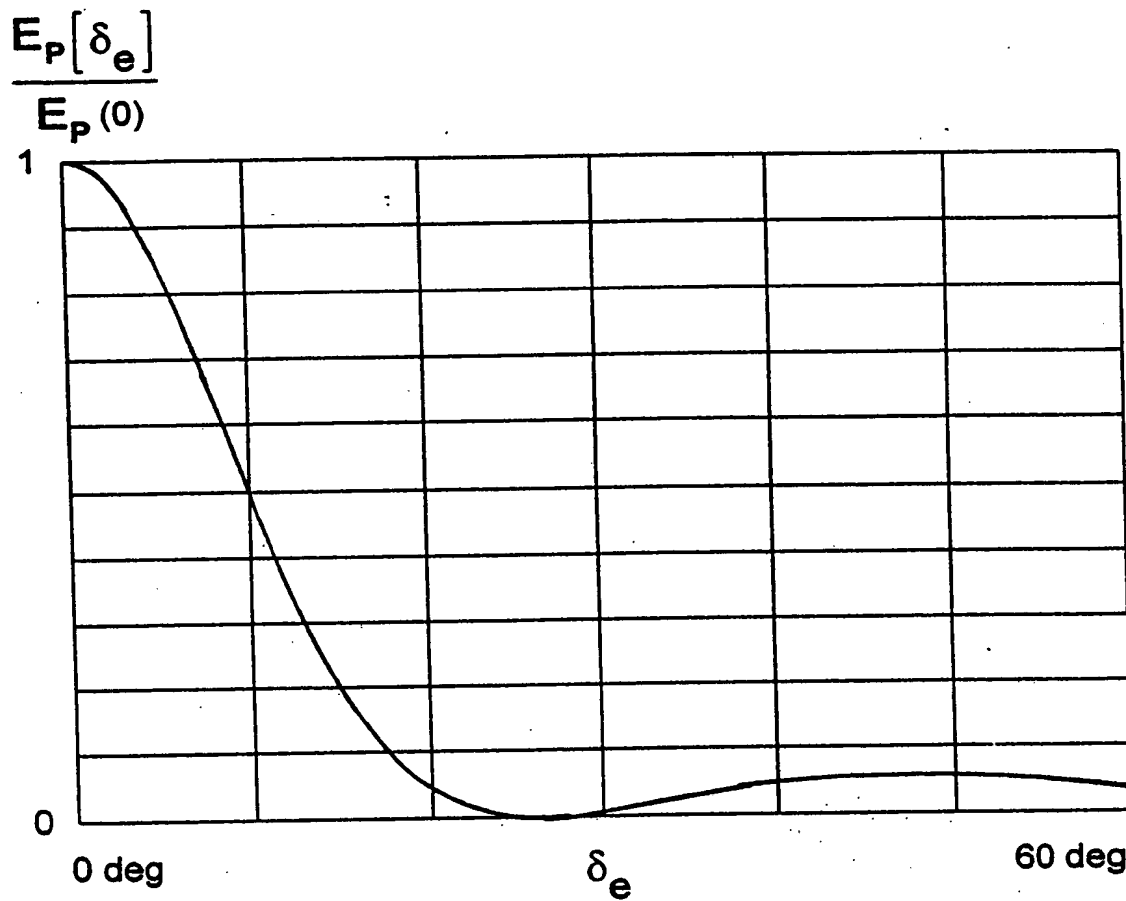


FIG. 38C2



GEOMETRICAL MODEL OF LIGHT COLLECTION  
SUBSYSTEM

$A = 52.9^\circ$   
 $B = 24^\circ$

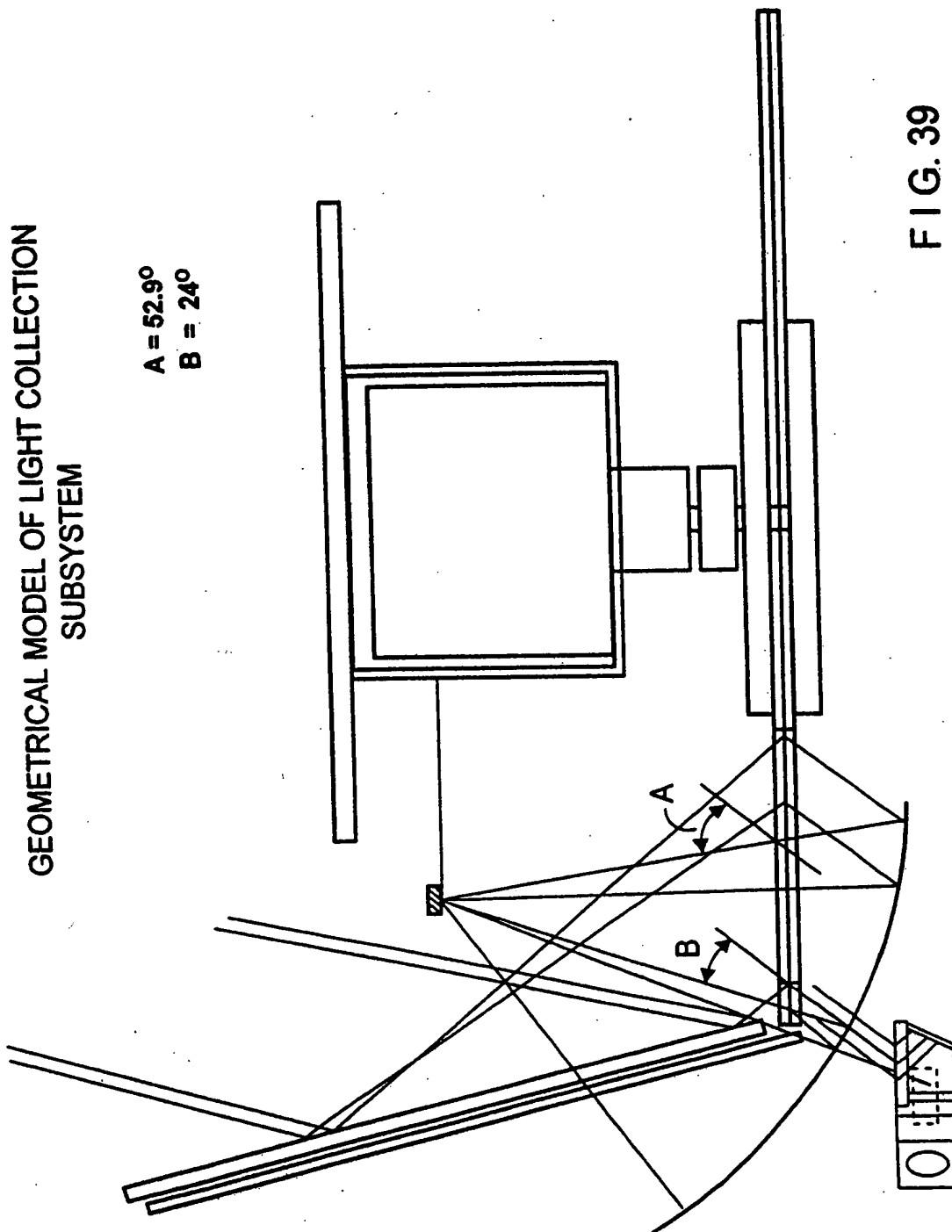


FIG. 39

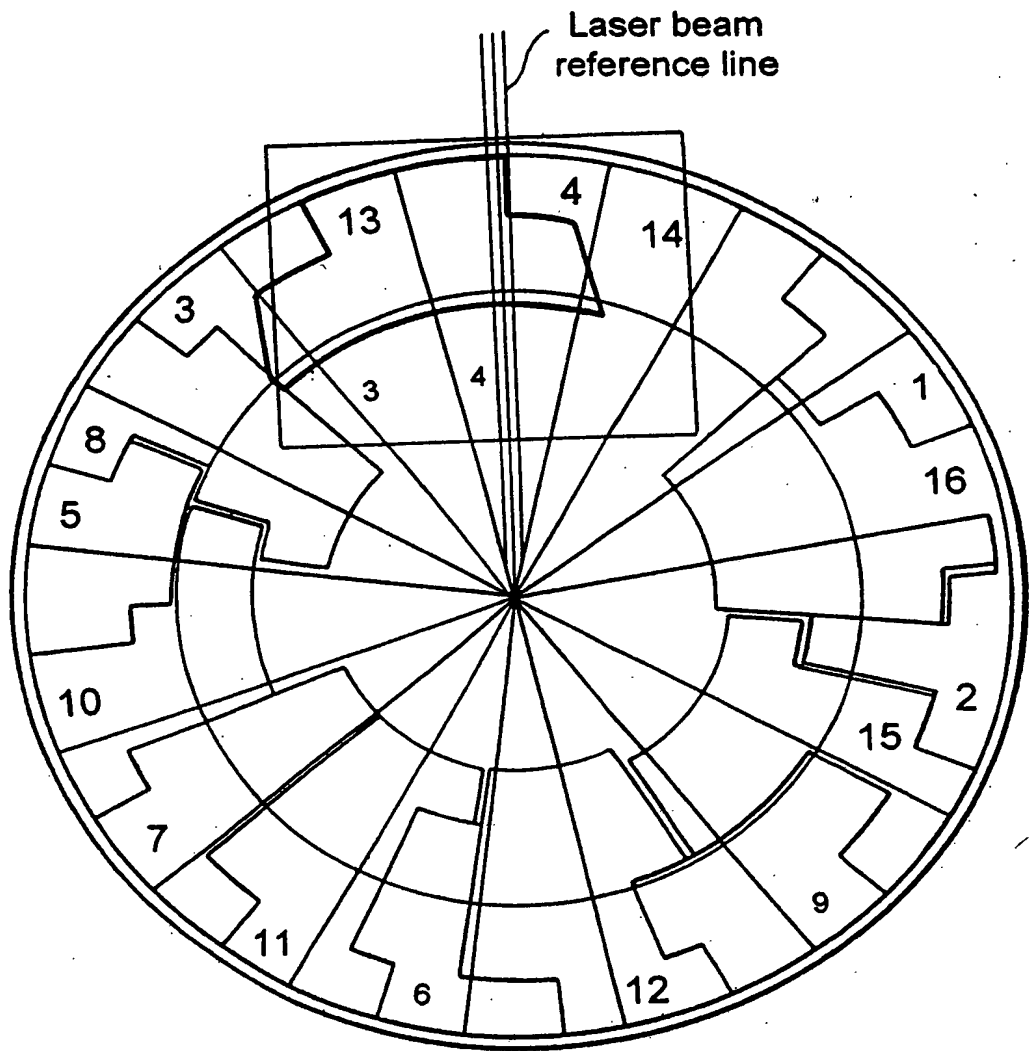


FIG. 40A

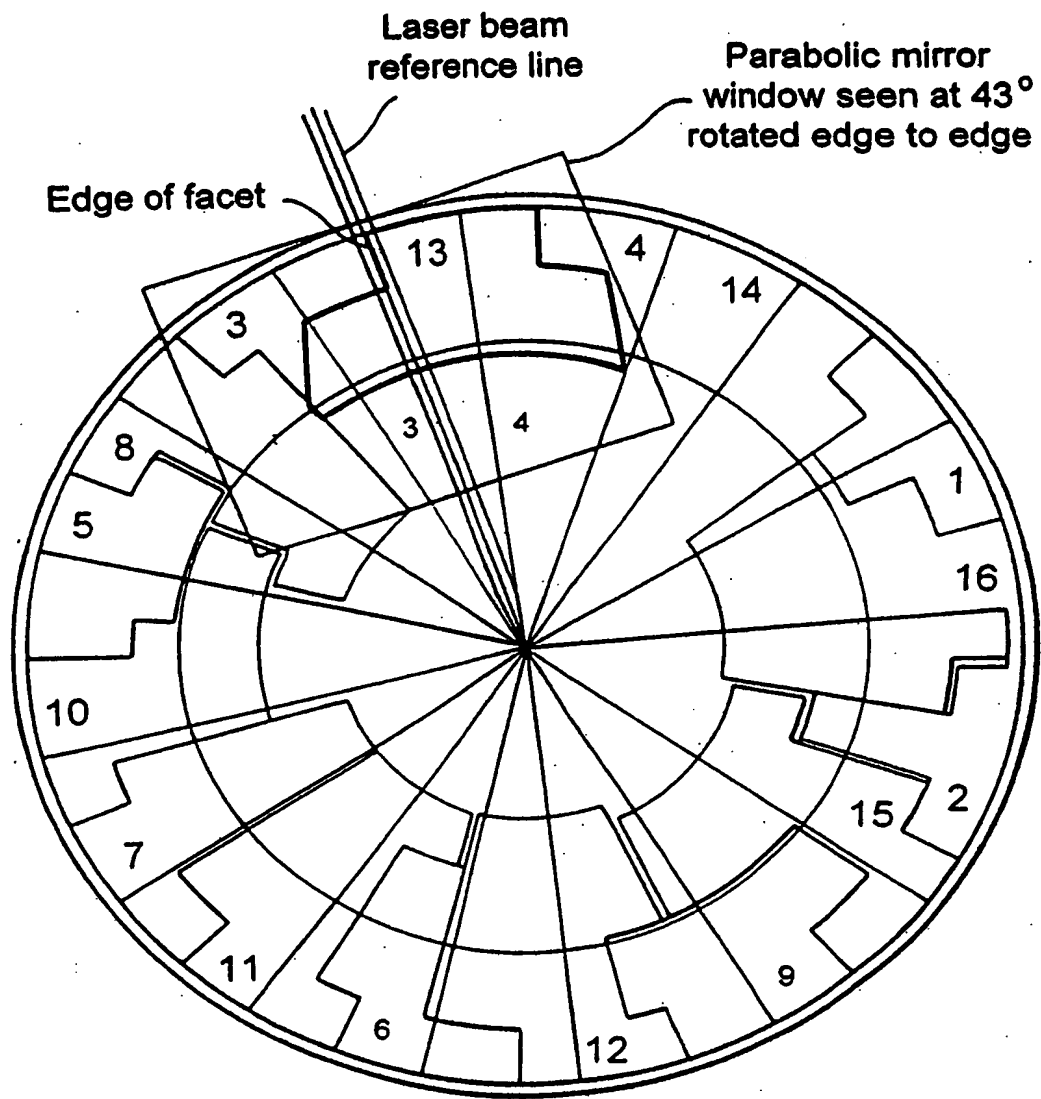


FIG. 40B

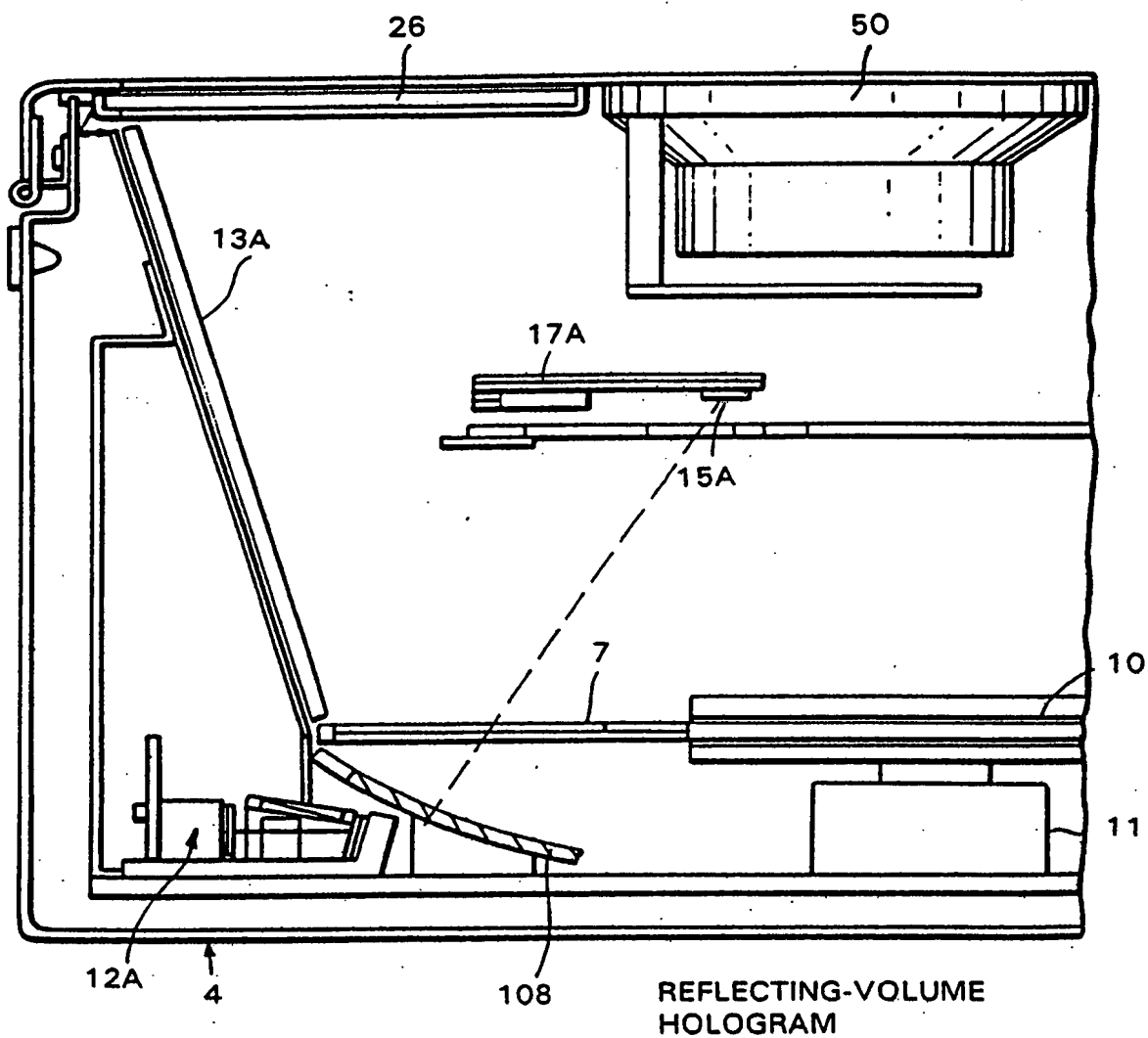


FIG. 41



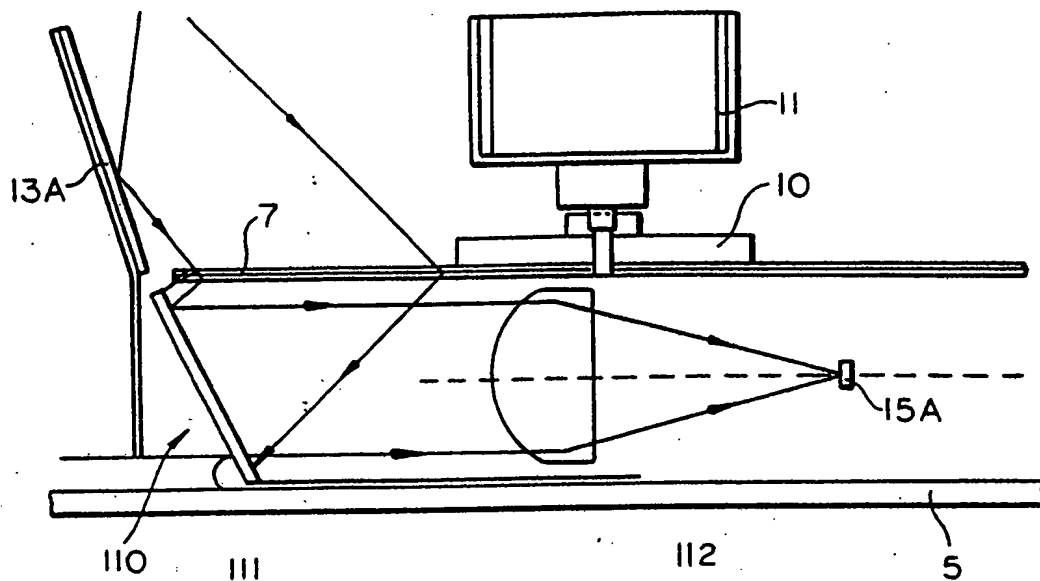


FIG. 42

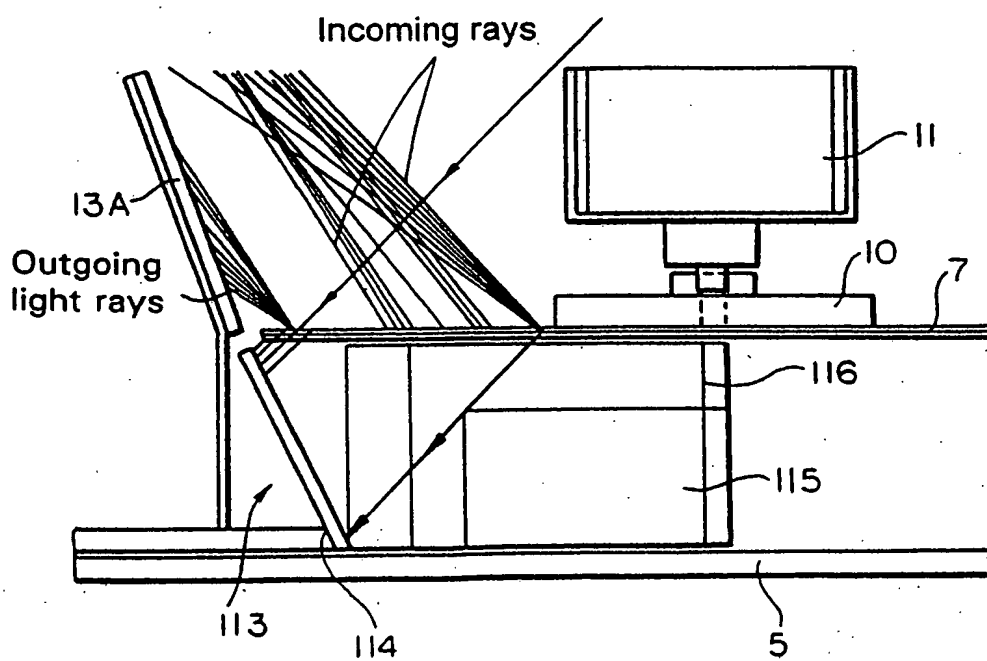


FIG. 43A

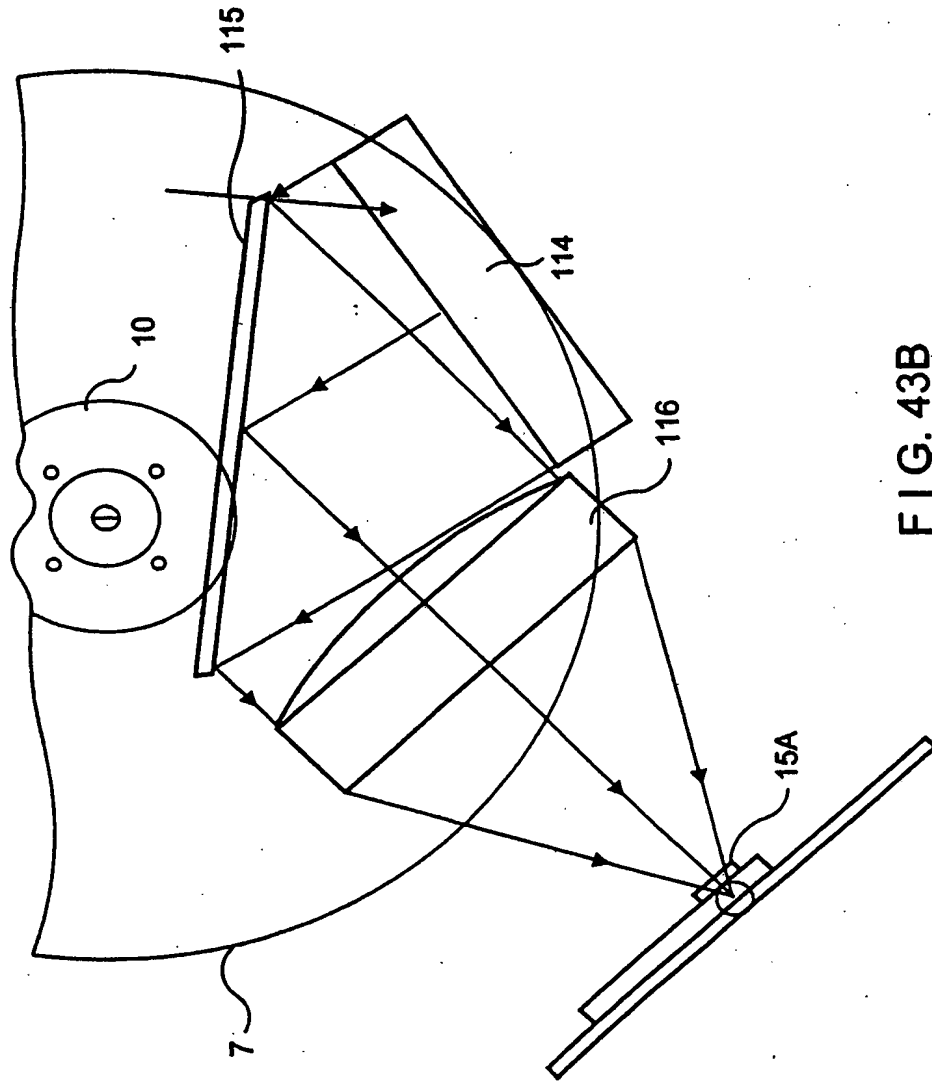
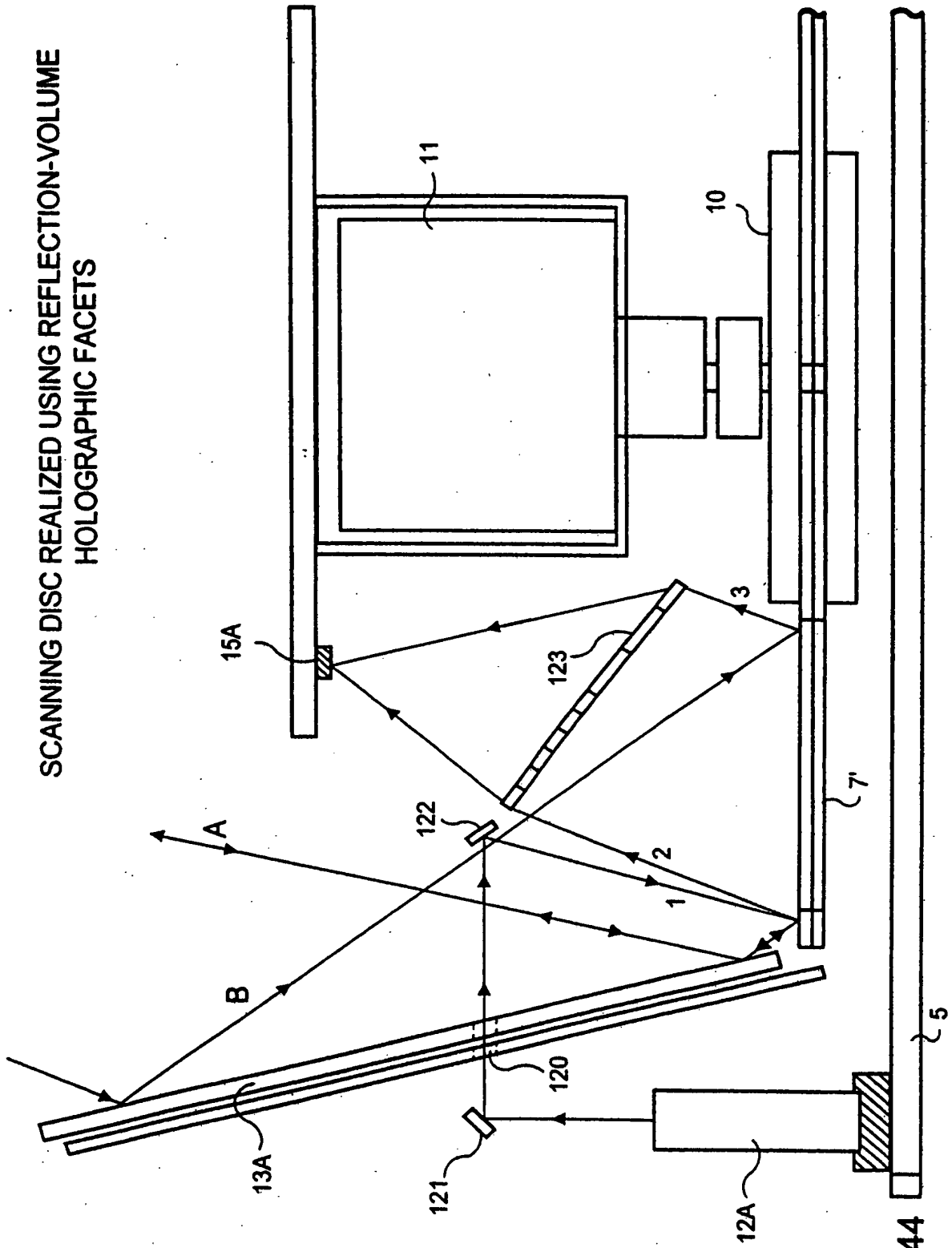


FIG. 43B



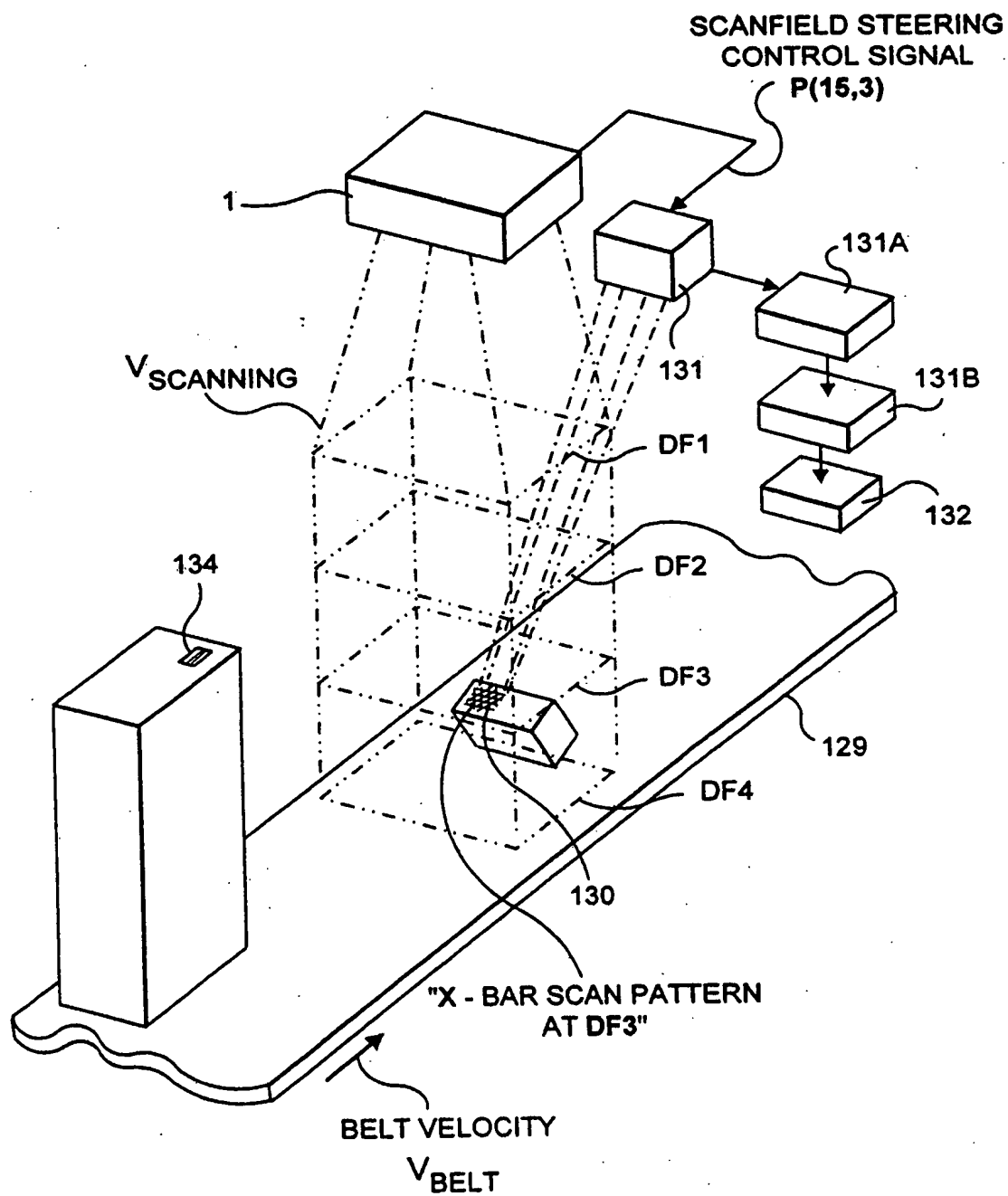


FIG. 45A

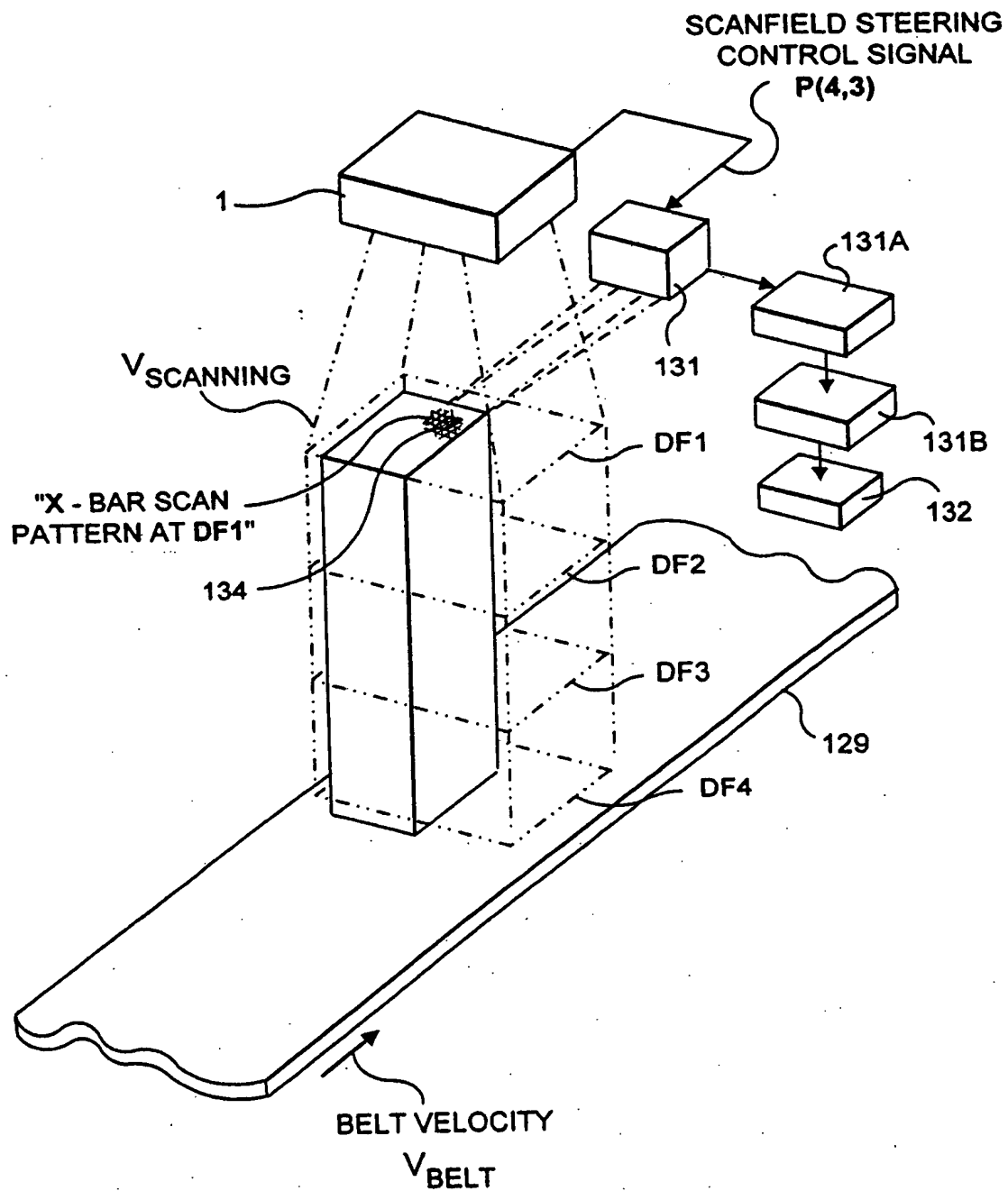


FIG. 45B

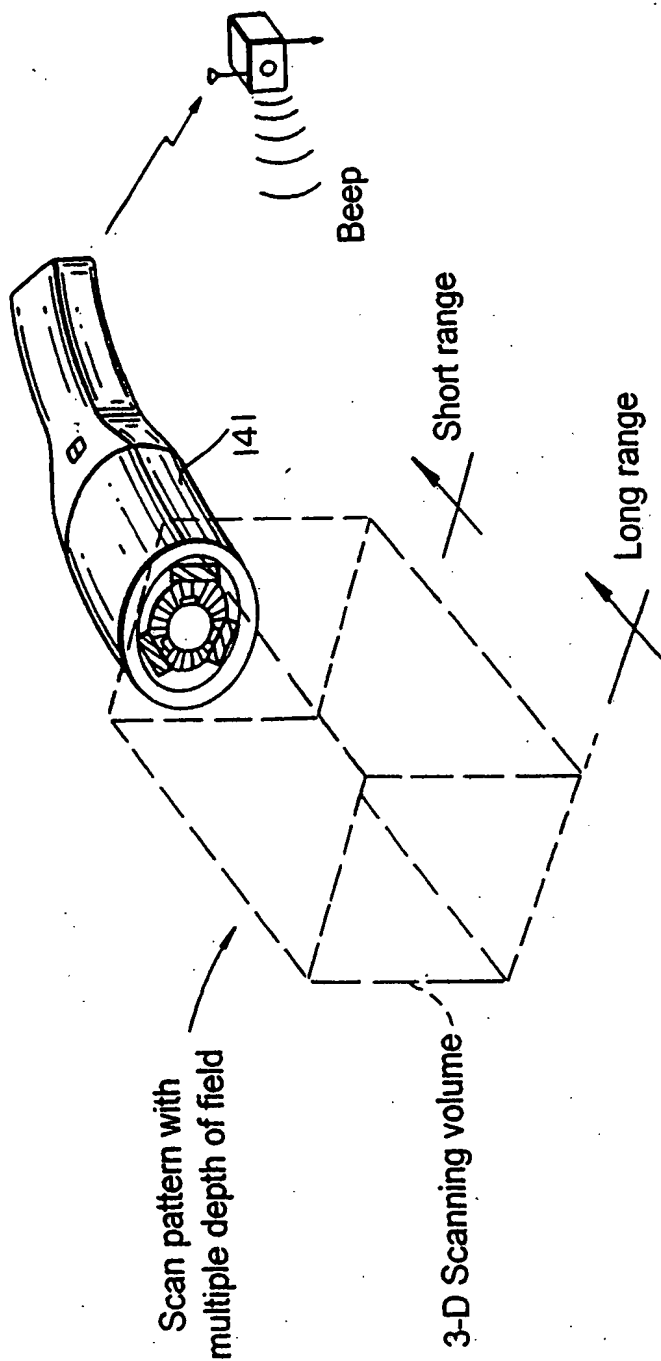


FIG. 46

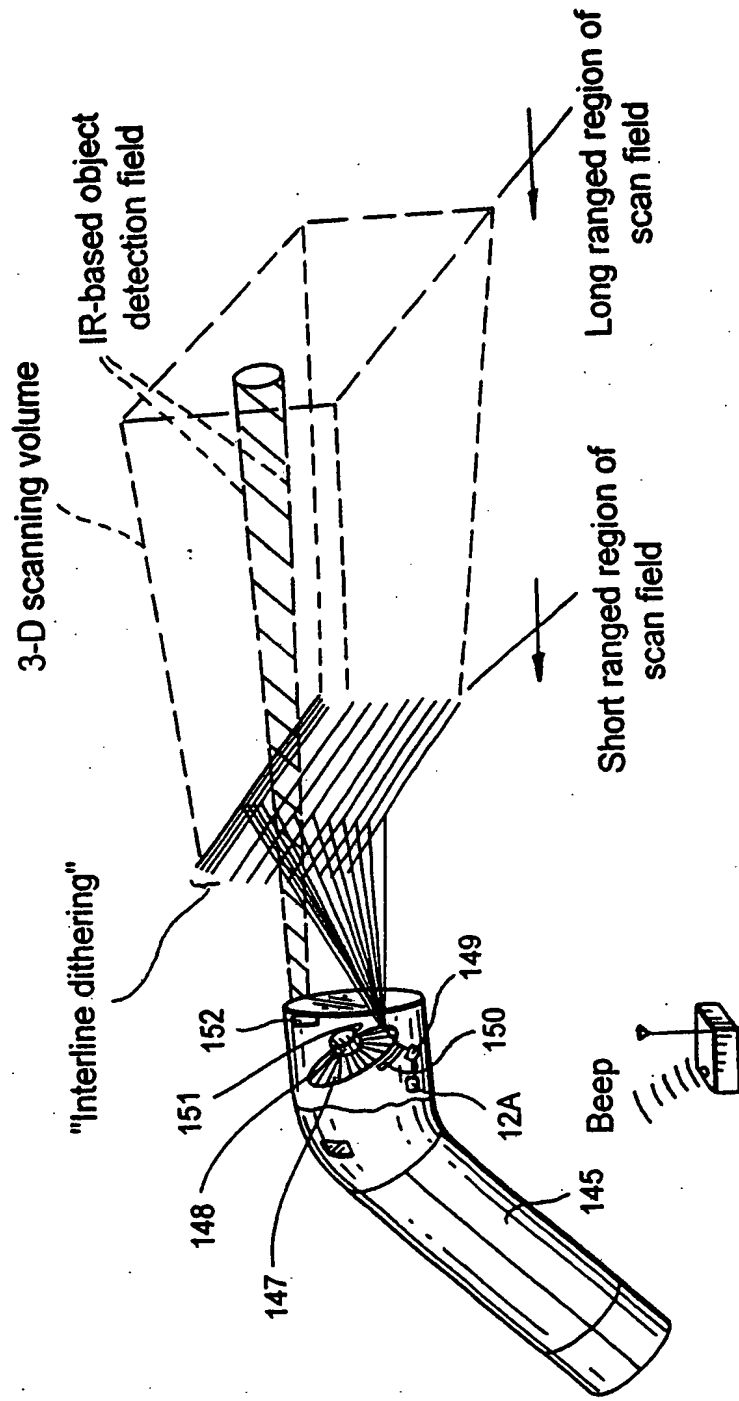


FIG. 47

